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Assessment of multiplied initial wheat seed material for food production application

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A B S T R A C T

The comparative evaluation of wheat varieties grown as multiplied initial seed material under uniform agroecological and fertilisation conditions revealed differences in morphophysical, chemical and techno-functional properties relevant for the application in the food industry. The samples analysed included the 'Galenika' variety and three introduced varieties (two Swedish and one Russian wheat), each grown on soils of similar quality. The morphological characteristics (ear length, number of ears per head, number of grains per ear, weight of grains per wheat class, number of grains per wheat class and the weight of wheat chaff), chemical composition (moisture, ash, protein, lipid, carbohydrate, starch content, wet gluten and acidity) were evaluated and statistically significant differences were found between the samples. The physical and chemical characterisation of the samples was determined using standardised methods. The highest starch content (64.13%) was found in the Swedish variety, which was associated with a lower protein content. The Russian wheat variety had a lower starch content (59.25 %) and a slightly higher protein and lipid content. The chemical composition of the samples indicates the potential suitability of these wheat varieties for various food applications (bakery products, pasta, starch-enriched products, etc.), especially where a specific starch-protein balance is required for technological and nutritional optimisation. The WHC, OAC and SRC values showed functional and technological differences between the samples, indicating their suitability for various food applications, especially in bakery. The role of initial seed material in improving the agricultural productivity and functional performance of wheat-based food systems could be of great importance.

Keywords: wheat varieties, morphology, chemical composition, techno-functional characteristics

И З В О Д

Компаративна евалуација сорти пшенице гајених као умножен почетни семенски материјал у истим агроеколошким условима и условима ђубрења показала је разлике у морфофизичким, хемијским и техно-функционалним својствима значајним за примену у прехрамбеној индустрији. Анализирани узорци обухватили су сорту Галеника и три умножене сорте (две шведске и једну руску пшеницу), од којих је свака гајена на земљишту сродног квалитета. Утврђене су морфолошке карактеристике (дужина класа, број класића у класу, број зрна у класу, тежина зрна у класу, број зрна у класићу и маса плевице), хемијски састав (влага, пепео, протеини, липиди, садржај угљених хидрата и скроба, влажни глутен и киселост) са статистички значајним разликама између узорака. Физичка и хемијска карактеризација узорака је утврђена стандардизованим методама. Највећи садржај скроба (64.13%) имала је шведска сорта, што је било повезано са нижим садржајем протеина. Руска сорта пшенице имала је смањен ниво скроба (59.25%) и нешто већи садржај протеина и масти. Хемијски састав узорака указивао је на потенцијалну погодност ових сорти пшенице за различите примене у прехрамбеној индустрији (пекарски производи, тестенине, производи обогаћени скробом итд.), посебно када је потребан специфичан баланс скроба и протеина за технолошку и нутритивну оптимизацију. Вредности КЗВ, КЗУ и СРЦ су показале функционалне и технолошке разлике између узорака, што је указало на потенцијал њихове примене у производњи различитих прехрамбених производа, посебно у пекарству. Улога умноженог семенског материјала у побољшању пољопривредне продуктивности и функционалних перформанси прехрамбених система на бази пшенице могла би бити од значаја.

Кључне речи: сорте пшенице, морфологија, хемијски састав, техно-функционалне карактеристике

1. Introduction

Wheat is one of the most widely cultivated crops in the world and plays a key role as a source of carbohydrates in the human diet (Khalid et al., 2023). The final use of wheat, especially its application in the baking industry, is mainly based on a combination of its morphological, physical, chemical, functional and technological properties, parameters that all determine the grain quality (Mitura et al., 2023; Hoque and Islam, 2024). Different wheat varieties differ greatly in their grain quality parameters (Živančev et al., 2022; Mitura et al., 2023; Rozbicki et al., 2015; Laidig et al., 2017). 'Galenika' is a Serbian wheat variety that is resistant to local agroclimatic conditions and has high yield and quality potential (Madić et al., 2025). Swedish wheat varieties are also known to be tolerant to low temperature stress and show stable performance in grain yield and protein content under different agroclimatic conditions (Vaitkevičiūtė et al., 2023; Ingver et al., 2024). Russian bread and durum wheat varieties have been selectively bred to increase protein content, gluten content and grain quality to be suitable for converging agroclimatic conditions and to obtain the required quality for various end uses such as bakery and pasta products (Natoli et al., 2021; Malchikov et al., 2024; Gordeeva et al., 2025).

The morphological and physical properties of wheat grains influence not only the efficiency and yield of milling, but also the technological, functional and chemical properties of the grain, which are decisive for the end-use quality in the production of bakery products (Dziki et al., 2014; Khalid et al., 2023; Lakić-Karalić et al., 2021). The chemical composition (protein and wet gluten content) is decisive for the firmness and elasticity of the dough, which in turn are crucial for the quality of bread and pasta products (Khalid et al., 2023; Mato et al., 2023).

The water holding and oil absorption capacity of flour is one of the most important properties for product texture, sensory acceptance and storage stability; the better the machinability of the dough for baking applications, the higher the water holding capacity value, and the greater the flavour binding, the higher the oil absorption capacity value (Arepally et al., 2023; Awuchi et al., 2019). Solvent retention capacity tests, which measure the interaction of the flour with a range of solvents (e.g. sodium carbonate, lactic acid, sucrose), are a useful predictor of gluten strength, starch damage and pentosan content and thus a general indicator of flour performance during processing (Kweon et al., 2011).

The aim of this study was to determine the possibility of cultivating initial multiplied wheat seeds from other areas of the Republic of Serbia and to characterise them in order to predict the possibilities of their use in the food industry.

2. Materials and methods

2.1. Materials

The experimental material comprised four wheat samples: the variety 'Galenika' Avenue (Serbia), which was used as a control sample (C), two varieties originating from Sweden (PU I and PU II) and one variety originating from Russia (PU III). The exact variety names of the Swedish and Russian wheat were not specified by the supplier. The materials were labelled with their origin and trial designation for propagation purposes. The Swedish and Russian varieties were multiplied initial seed material from the respective countries, which were subsequently propagated under uniform agroecological conditions in the Kolubara district in central Serbia.

The wheat crops of all varieties were grown under regular agricultural conditions, taking into account the soil class, fertilisation and planting times corresponding to the requirements of each variety. The Russian and the 'Galenika' wheat variety were grown on soils of quality class IV, with a basic fertilisation of 150–200 kg/ha of NPK fertiliser and a top dressing of 250 kg/ha of ammonium nitrate. 'Galenika' and the Russian wheat variety were grown under identical growing conditions, reflecting the similarity of the agroclimatic conditions in their regions of origin. Both varieties were grown on soils that are typical for local production.The Swedish varieties were grown on class II soils, followed by a vegetable crop (potato) and fertilised with 150 kg/ha of NPK fertiliser and 200 kg/ha of ammonium nitrate for top dressing. The choice of soil quality and fertilisation was made in an attempt to approximate the typical growing conditions in Sweden, where these varieties originate from, to ensure that the growing conditions reflect the agro-ecological background of the samples.Wheat samples were milled in a laboratory stone mill (Trstenik, Serbia) equipped with 70 cm diameter stones and operated at a constant speed of 700 rpm. Before milling, the grains were cleaned by hand and conditioned to a moisture content of approx. 15 %. The grains were then allowed to equilibrate for 24 hours to achieve a uniform moisture content, as described by Kweon et al. (2009). The 'Galenika' variety was milled into refined white flour and used as a control sample to represent the industrial standard reference, while the other varieties were milled into wholemeal flour. White flour was obtained by sieving through a 160 μm sieve, which allowed the removal of bran and germ particles and ensured a uniform particle size. Wholemeal flours were used without fine sieving, except for homogenisation through a 500 μm sieve to remove only the largest bran particles and improve sample consistency.

2.2. Determination of morphological characteristics

The morphological characteristics were determined using a representative set of wheat plants harvested at maturity. The following characteristics were determined:

- ear length (mm): measured manually from the base to the tip of the main ear, excluding awns according to Khare and Singh (2023);
- number of ears per plant: counted by hand on each individual wheat plant according to Gu et al. (2023);
- number of grains per ear: determined by manually threshing selected ears and counting the grains according to Fernandez-Gallego et al. (2018);
- weight of grains by wheat class (g): measured on an analytical balance with an accuracy of 0.001 g according to Knežević et al. (2015);
- number of grains by wheat class: manually counted according to Knežević et al. (2015);
- weight of wheat chaff (g): determined by subtracting the weight of the threshed ear minus the weight of the grains according to Suardi et al. (2020).

All morphological measurements were carried out on at least 20 randomly selected plants per sample to ensure reproducibility and statistical validity.

2.3. Determination of physical characteristics

The physical characteristics of the wheat grains were evaluated according to globally recognised standards. The hectolitre weight and thousand kernel weight (TKW) were determined in accordance with ISO 7971-1:2009 and ISO 520:2010, respectively. The grain size, i.e. thickness, width and length, were determined manually using a precision micrometer with an accuracy of 0.01 mm. For statistical relevance, at least 20 randomly selected grains per sample were used for the measurement.

2.4. *Proximate composition analysis*

The chemical composition of the wheat samples was determined according to standard analytical protocols to ensure accuracy and comparability. The wheat samples were ground in a coffee grinder (Bosch, model TSM6A013B). Grinding was performed to produce fine flour and the mill was left on standard settings to maintain a constant particle size for subsequent analysis. All samples were milled in the same way and under the same conditions.

Moisture, ash, protein and lipid content were determined according to ISO 712-1:2024, ISO 2171:2023, ISO 20483:2013 and ISO 659:2009, respectively. The total nitrogen content was determined and multiplied by a factor of 5.7 to determine the crude protein content in wheat samples as reported by Rekowski et al. (2021). Crude fat content was determined by acid hydrolysis pretreatment and Soxhlet extraction according to the Weibull-Stoldt method (Kolar et al., 1993). Carbohydrate content was calculated using the formula given in Konkubaeva et al. (2023).

The starch content of the samples was determined using the polarimetric method according to ISO 10520:1997. The wet gluten content and acidity were determined according to ISO 21415-1:2006 and ISO 7305:2019, respectively.

2.5. *Determination of functional properties*

The functional properties of the flour samples were determined with regard to their water holding capacity (WHC) and oil absorption capacity (OAC) according to the method described by Zlatanović et al. (2019). One gram of the flour was mixed with 10 mL of water (for WHC) or refined vegetable oil (for OAC) in a centrifuge tube for each determination. The suspensions were allowed to stand at room temperature for 24 hours. After centrifugation at 3600 rpm for 20 minutes, the supernatant was poured off by slow pouring and the weight of the remaining water or oil was determined. WHC and OAC are expressed as grams of liquid absorbed per gram of flour (g/g).

2.6. *Determination of technological properties*

The technological properties of the flour were determined according to the method described in Laličić-Petronijević (2018). The solvent retention capacity (SRC) was tested in distilled water (SRC water), 50% sucrose solution (SRC sucrose), 5% lactic acid solution (SRC lactic acid) and 5% sodium carbonate solution (SRC sodium carbonate). Approximately 5 g of flour was mixed with 25 g of each solvent, shaken every 5 minutes and equilibrated at room temperature for 25 minutes and centrifuged at 3000 rpm for 15 minutes. The weight of the sediment was measured and the SRC was determined as the percentage of retained solvent to the original flour weight.

2.7. Statistical analysis

The data obtained were statistically analysed using analysis of variance (ANOVA). Significant differences between the mean values were determined using the Tukey test for honestly significant differences (HSD) at a significance level of 5 ($p < 0.05$). All statistical analyses were performed using the statistical software STATISTICA 12.

3. Results and Discussion

3.1. Wheat morphological characteristics

Visual observations of 'Galenika' and the Russian variety showed that the first and last ears contained a smaller number of grains, which were also finer. In contrast, the middle part of the ear had three grains of uniform size, which was consistent with the results of Wang et al. (2024). This distribution indicates a more uniform grain arrangement in the middle part of the ear. The Swedish varieties were uniform in both the number of grains and earlets, which was consistent with the results of Regnér et al. (1994). The first earlet contained three grains, followed by four well-developed grains of uniform size. These results indicate that the Swedish varieties have a higher degree of uniformity in grain development compared to others, with a uniform grain number and size across the ears. The morphological characteristics of the wheat were shown in Table 1.

Table 1.
Morphological characteristics of wheat samples ± standard deviation (SD)

Parameters	C	PU I	PU II	PU III
Length of ears (mm)	106.40±0.39 b*	105.90±0.78 b	116.30±0.48 a	119.00±0.42 a
Number of ears per head of wheat	19.67±0.58 b	20.00±1.73 ab	18.67±2.08 b	23.67±0.58 a
Number of grains per ear of wheat	3.00±0.00 a	3.40±0.55 a	3.20±0.45 a	3.00±0.00 a
Weight of grains per wheat class (g)	2.09±0.09 a	2.12±0.34 a	2.09±0.15 a	2.45±0.26 a
Number of grains per wheat class	44.67±3.05a	53.67±7.20a	46.33±6.43a	58.00±6.24a
Weight of wheat chaff (g)	0.23±0.04 c	0.26±0.12 bc	0.43±0.04 ab	0.55±0.05 a

*Different letters in the row indicate a significant difference according to Tukey's test ($p < 0.05$). C–control; PU I – Swedish wheat variety 1; PU II – Swedish wheat variety 2; PU III – Russian wheat variety.

Samples PU II and PU III had a greater ear length (116.30 mm and 119.00 mm, respectively) than samples C and PU I (106.40 mm and 105.90 mm, respectively). Yadav et al. (2013) reported that both the number of earlets per ear and ear length exerted the most significant positive influence on grain yield, highlighting their potential as important selection criteria in wheat breeding programmes.

Sample PU III had the highest number of ears per head (23.67), far ahead of the control (19.67), PU I (20.00) and PU II (18.67). This indicates that the PU III sample promoted tillering or reduced ear breakage, resulting in a higher number of ears. Such deviations can be attributed to differences in the cultivation systems according to Paunescu et al. (2023).

The number of grains per ear remained relatively similar between the samples, ranging from 3.00 to 3.40 grains. According to the results, the samples differed in terms of ear length and number, but not significantly in terms of the number of grains per ear, which was also found in Sanchez-Bragado et al. (2016). According to Jiang et al. (2024), the number of grains per ear can be influenced by the environmental conditions during the flowering period.

The highest grain weight was found in sample PU III – 2.45 g, while the other samples showed 2.09 g (C, PU II) and 2.12 g (PU I). Better assimilate distribution or increased photosynthetic capacity could be responsible for the higher grain weight of PU III, and this could have contributed to better grain filling, as Foulkes et al. (2011) stated in their work.

The number of grains per class varied, with the highest in PU III at 58.00, followed by PU I (53.67), PU II (46.33) and control (44.67). This is an indication of fertility and successful pollination of flowers per ear. Higher grain numbers per class, as in PU III, may be due to good environmental conditions and effective agronomic management that improves flower fertility as Zheng et al. (2016) reported.

Chaff weight, the non-grain part of the ear, was highest in PU III at 0.55 g and lowest in the control at 0.23 g. While a higher chaff weight indicates more robust ear structures, it may also indicate a trade-off between structural biomass and grain yield (Rebetzke et al., 2016).

3.2. Physical characteristics

Physical properties of wheat such as grain size, hectolitre weight and thousand kernel weight (TKW) are major factors that determine wheat quality as well as milling performance of wheat (Wang and Fu, 2020). The physical characteristics of different wheat types are shown in Table 2.

Table 2.
Wheat grains physical characteristics ± standard deviation (SD)

Parameters	C	PUI	PUII	PUIII
Length (mm)	6.02±0.16 b	7.47±0.61a	8.10±0.57 a	6.10±0.12 b
Width (mm)	3.21±0.31 b	3.92±0.43 a	3.81±0.36 a	2.87±0.21 b
Thickness (mm)	1.95±0.38 b	2.78±0.30 a	2.67±0.41 a	2.03±0.07 b
Hectolitre weight (kg hL^{-1})	68.55±0.15 c	68.65±0.23 c	73.35±0.10 b	74.25±0.03 a
Thousand kernel weight (g)	34.01±0.20 c	40.91±0.12 b	42.32±0.05 a	33.41±0.56 c

*Different letters in the row indicate a significant difference according to Tukey's test (p<0.05). C – control; PU I – Swedish wheat variety 1; PU II – Swedish wheat variety 2; PU III – Russian wheat variety.

The length of wheat grains showed great differences between different wheat types. PUII and PUIII had the longest grains with a mean value of 8.10mm and 7.47 mm, respectively. In contrast, varieties C and PUI had shorter grains with a mean value of 6.02 mm and 6.10 mm, respectively. Grain thickness and width also showed large differences. PUI and PUII had the widest and thickest grains, 3.92 and 2.78 mm and 3.81 and 2.67 mm, respectively. Conversely, narrower and thinner grains in C and PUIII could lead to lower milling yield and higher ash content in the flour, as suggested by Metcalfe et al. (2022).

The hectolitre weight, an important physical quality parameter for grain, represents the bulk density and is often used by the milling industry. Factors such as weather damage, shrivelled or immature grains, and rain-induced germination reduce the hectolitre weight (Okuyama et al., 2020) and changes in the moisture content of wheat grains (Manley et al., 2009). This parameter is usually between 60 and 84 kg hL^{-1} for wheat. High-quality wheat is generally characterised by a hectolitre weight of more than 76 kg hL^{-1} (Madić et al., 2024; Okuyama et al., 2019). The hectolitre weight was highest in PUIII (74.25 kg hL^{-1}) and PUII (73.35 kg hL^{-1}), indicating denser grains. In contrast, C and PUI showed lower values, which could indicate differences in grain composition and density. The TKW was also highest for PUII (42.32 g) and PUI (40.91 g), suggesting better grain filling and the potential for better processing quality, as reported by Wang and Fu (2020).

The physical characteristics of grains are important because they can be used to predict the quality of flour and later its possible uses. For example, Acar et al. (2019) found that smaller grains have a greater hardness, which leads to a lower flour yield, and that smaller grains are characterised by a lower protein and wet gluten content. Jeet Kaur and Talekar (2021) also confirmed that the chemical composition of wheat, especially the protein content, can influence its physical characteristics. The same authors reported that higher protein content can lead to denser grains, which increases the hectolitre and TKW.

3.2. Proximate composition

The compositional parameters of wheat grains, moisture, ash, protein, and lipid content were presented in Figure 1. Moisture content is a critical factor affecting the storability of grain and susceptibility to microbial spoilage (Qui et al., 2024). In this study, the moisture content of the samples was relatively constant and ranged from 11.25% (PU III) to 11.46% (PU II). The moisture content was very similar in all samples and was within the limits prescribed by the Regulation on the Quality of Cereals, Milled and Bakery Products and Pasta (max. 14.5%).

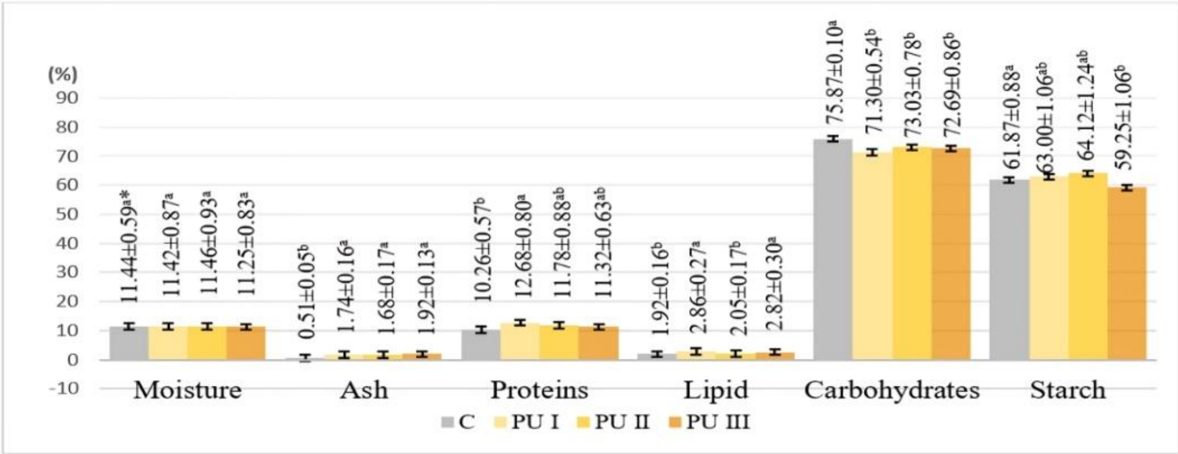

Figure 1. Wheat grain flour composition.
*Different letters in the column indicate a significant difference according to Tukey's test ($p < 0.05$). C – control; PU I – Swedish wheat variety 1; PU II – Swedish wheat variety 2; PU III – Russian wheat variety.

The ash content indicates the total mineral composition of the grain, which is an important factor for the nutritional value and processing properties (Bodor et al., 2024). The results showed a significant increase in the ash content of all samples except sample C, which had the lowest ash content at 0.51%, while PU III had the highest at 1.92% (Figure 1). According to Bodor et al. (2024), the increased ash content could be related to the mineral-rich non-endosperm parts of the wheat, such as bran and germ.

Protein content is a quality parameter that also influences the nutritional quality and functional properties of wheat flour (Chinma et al., 2024). In Figure 1, it can be seen that the control had the lowest protein content of 10.26%, while PU I had the highest value of 12.68%. This increase in protein content in PU I can be attributed to the higher proportion of wheat bran in the flours, as noted by Li and Wu (2024). The composition and protein content of wheat grains, especially the quantitative and qualitative differences in protein content, can significantly influence the baking process of end products and improve the quality of the end product, especially baked goods (Sharma et al., 2020; Goel et al., 2021)

Although the lipid content is a small percentage of the wheat grain, it affects the shelf life of wheat products (Siraj, 2022). The control sample contained the lowest 1.92% lipid content, while PU I and PU III contained significantly higher 2.86% and 2.82%, respectively (Figure 1). This could be due to the increased lipid content in germ and bran, as reported by Geng et al. (2015) in their paper. Depending on the chemical composition of the lipids, the compounds can influence the mixing, and change the starch properties by complexing with the amylase fraction and thus the gluten development, which depends on the baking quality (Mikolasova et al., 2022)

Carbohydrates make up the largest proportion of the composition of the wheat grain, mainly in the form of starch, and determine the energy value (Szuba-Trznadel et al., 2024). The control sample had the highest carbohydrate content at 75.88%, while PU I had the lowest at 71.30%, as shown in Figure 1. The decrease in carbohydrate concentration can be explained by a negative linkage between protein concentration and grain yield according to Geyer et al. (2022). According to the literature, increasing carbohydrate enrichment (yield) is accompanied by a decreasing protein concentration, while a decreasing carbohydrate content is accompanied by an increase in protein concentration (Geyer et al., 2022; Khalid et al., 2023).

The starch content showed clear differences between the wheat samples tested. The results are shown in Figure 1. PU II had the highest starch content (64.12%), followed by PU I (63.00%) and C (61.87%), while PU III had the lowest (59.25%). Gebruers et al. (2008) determined starch contents between 61% and 68%, depending on genotype and growing conditions. The differences in starch content between the samples could also be explained by the different chemical composition, especially the protein and moisture content, as Guo et al. (2023) found. Sample PU III, which had the lowest starch content, also had the highest protein (11.96%) and moisture (12.40%) content (Figure 1). This result is consistent with previous studies showing a negative correlation between starch and protein content in wheat grains, as nitrogen allocation for protein synthesis is often at the expense of starch accumulation (Guttieri et al., 2001; Zhao et al., 2009). Since starch content affects technological properties relevant to food production, such as bread baking performance (Baik and Ullrich, 2008), the results of this study suggest that PU II may be better suited for applications in the food industry that require improved starch functionality.

The wet gluten content of the samples is given in Table 3. The variations in the wet gluten contents of the samples reflect the effects of the most influential parameters of the chemical composition (protein, ash, moisture and lipid). The lowest wet glue content (15.76%) was found in the C and the highest (22.53%) in PU I, followed by PU II (20.39%) and PU III (17.31%). These results were in agreement with Kaushik et al. (2014), who found that the development of gluten depends on protein concentration. The higher protein content of PU I (12.68%) and PU II (11.78%) (Figure 1) also resulted in higher wet gluten content compared to the control (15.76%) (Table 3). PU III also had a lower wet gluten content, while the protein content was relatively moderate (11.32%), which may be due to the wheat type and lipid content, as

Yu Li et al. (2013) found. Bodor et al. (2024) described the way in which variations in ash and water content can influence the wet gluten content in wheat flour. White wheat flour had higher water and wet gluten content and lower ash content than whole wheat flour (Bodor et al., 2024). Higher ash content is associated with whole grain flours or minimally processed flours as they can weaken the gluten network due to the presence of non-gluten components (Wieser and Kieffer, 2001). This finding is consistent with the results presented in this paper, in which sample PU III had the highest proportion of ash (Figure 1) and the lowest content of wet gluten (Table 3). The lipid content in flour can influence the development of the gluten network. Increased lipid content can interact with gluten proteins and impair their hydration and aggregation properties, which in turn can affect the overall quality of the gluten (Schopf et al., 2021).

Table 3.
Wet gluten and acid degree value (ADV) ± standard deviation (SD)

Parameters	**C**	**PU I**	**PU II**	**PU III**
Wet gluten (%)	15.76±0.65 b	22.53±1.04 a	20.39±0.85 a2	17.31±1.11 b
Acid degree value (mg NaOH/100g)	1.50±0.17 a	1.42±0.16 a	1.40±0.16 a	1.50±0.16 a

*Different letters in the row indicate a significant difference according to Tukey's test ($p < 0.05$). C – control; PU I – Swedish wheat variety 1; PU II – Swedish wheat variety 2; PU III – Russian wheat variety.

Acid degree values (ADV) were consistently between 1.40 mg NaOH/100g and 1.50 mg NaOH/100g for all samples. ADV is an indicator of lipid oxidation in foods such as flour and whole wheat flour (Siddique and Park, 2019). ADV monitoring evaluates the freshness and overall quality of flour products (Siddique and Park, 2019; Genag et al., 2023). Although there was no significant difference between the values, it is worth noting that ADV can be influenced by the chemical composition of wheat samples, with storage conditions having a greater impact (Konkubaeva, 2023), as shown in the current study.

These variations can be attributed to differences in genetic origin, agro-ecological conditions during propagation and interaction with other components of the composition.

3.4. Functional properties

The water holding capacity (WHC) and oil absorption capacity (OAC) were analysed to understand the functional properties of the samples. The results are shown in Table 4. The WHC is a measure of a flour's ability to absorb water and contributes to the hydration and texture of the dough as well as the quality of the final product (Berton et al., 2002; Murray et al., 2017).

Table 4.
Functional properties of sample ± standard deviation (SD)

Parameter (g/g)	**C**	**PU I**	**PU II**	**PU III**
WHC	1.01±0.15 a	0.99±0.10 a	0.84±0.13 a	1.06±0.19 a
OAC	1.19±0.15 a	1.04±0.15 a	1.02±0.11 a	1.04±0.11 a

*Different letters in the row indicate a significant difference according to Tukey's test ($p < 0.05$). WHC – water holding capacity; OAC – oil absorption capacity; C – control; PU I – Swedish wheat variety 1; PU II – Swedish wheat variety 2; PU III – Russian wheat variety.

The WHC of the samples ranged from 0.84 g/g (PU II) to 1.06 g/g (PU III). The WHC values were typical of standard refined wheat flour and indicated that hydrophilic components such as polysaccharides are present to a limited extent in all samples, which may affect the texture and stability of the product, as reported by Menon et al. (2014). According to Culet et al. (2021), flours with these WHC values are suitable for the production of cookies and crackers, i.e. products where a low WHC value contributes to crispness and less spreading of the dough during baking. According to Kotoki and Deka (2010), these flours are not only suitable for crackers and cookies, but also for bread production, as they can help to achieve the optimum crumb moisture, which determines the shelf life and freshness of the product. These slight differences in results can be attributed to the protein content, the particle size of the starch and the flour structure (Guerra-Oliveira et al., 2022; Agarwal et al., 2021). According to Guerra-Oliveira et al. (2022), differences in particle size or bran distribution, which determine water absorption in whole wheat flour, can be held responsible for lower water absorption. In addition, WAC is influenced by the spatial arrangement of protein and fibre matrices that facilitate water absorption (Arepally et al., 2023).

OAC is a functional property of flours that influences texture and flavour retention in various foods (Arepally et al., 2023). The interaction between the non-polar side chains of proteins in flour and lipids could generally be explained by higher oil absorption, which makes flours ideal for baked goods (Awuchi et al., 2019). The results of the OAC of the samples presented in Table 4 showed that the sample C had the highest oil absorption capacity of 1.19 g/g, while the other samples had slightly lower OAC values, ranging from 1.02 g/g (PU II) to 1.04 g/g (PU I and PU III). The OAC values of samples indicated a moderate oil retention capacity of the flour, which is useful in products where the preservation of flavour and texture is important, as stated by Rebolledo-Hernández et al. (2022). OAC values in the range of 1–1.38 g/g suggest a wide application in the food industry, e.g. in baked goods, meat products and gluten-free products, where it can contribute to moisture retention, texture and flavour improvement (Awuchi, 2019; EB et al., 2025).

3.5. Technological properties

The solvent retention capacity (SRC) test is a diagnostic tool for evaluating the technological properties of wheat flours by measuring their ability to retain certain solvents. This method according to Kweon et al. (2011) evaluates the contribution of gluten proteins, damaged starch and pentosans to the overall functionality of the flour. The four standard solvents used in SRC test include water, lactic acid, sodium carbonate and sucrose, each targeting specific components of the flour (Kweon et al., 2011). Lactic acid, sodium carbonate and sucrose SRC values respectively highlight glutenin performance, degree of starch damage and pentosan-induced water retention, each contributing to specific dough and product properties (Kweon et al., 2011). The SRC values of the samples are shown in Figure 2.

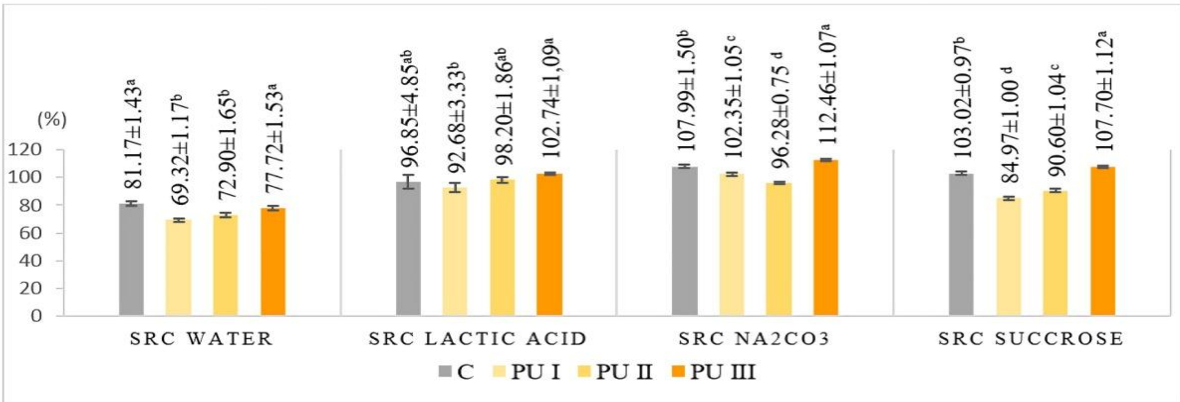

Figure 2. Wheat grain SRC values.

*Different letters in the column indicate a significant difference according to Tukey's test (p < 0.05). C – control; PU I – Swedish wheat variety 1; PU II – Swedish wheat variety 2; PU III – Russian wheat variety.

In this study, the SRC values of wheat flour samples were evaluated to determine their suitability for different bakery products based on their hydration, gluten strength, starch damage and pentosan content. The data provides information on the technological properties of the flours and their potential use in certain baked goods. The control sample C shows high water absorption (81.17%) and strong gluten potential (SRC lactic acid 96.85%), indicating its suitability for bread products requiring high hydration and fermentation capacity. The substantial damaged starch content (SRC Na_2CO_3 107.99%) is consistent with this, as it promotes fermentation, while the increased SRC sucrose (103.02%) indicates an increased pentosan content, which supports moisture retention and prolonged freshness of the final product. This combination of properties makes sample C ideal for products with higher moisture content and longer shelf life, such as artisan bread or bread with high moisture content (Kweon et al., 2011; Duyvejonck et al., 2011; Xiao et al., 2006). The sample PU I with a lower water absorption capacity (SRC water 69.32%) and a moderate adhesive strength (SRC lactic acid 92.68%) is better suitable for products that require minimal hydration, such as cookies and crackers. The average level of starch damage (SRC Na_2CO_3 102.35%) indicates that it can undergo limited fermentation without major problems. The reduced SRC sucrose value (84.97%) reflects a lower pentosan content, which contributes to the development of crisp, tender textures in baked goods that require less moisture retention and a crispier finish (Zimnicki et al., 2021; Kweon et al., 2011). The PU II sample, which has balanced water absorption, is well suited for products that do not require excessive hydration, such as flatbread or tortillas. The higher value of SRC lactic acid (98.20 %) indicates good gluten formation, which is best suitable for moderately elastic doughs, as Kweon et al. (2011) reported. In addition, the lower SRC sodium carbonate value (96.28 %) suggests minimal starch damage that promotes stable fermentation, while the moderate SRC sucrose value indicates a balanced pentosan content that supports controlled dough viscosity without compromising texture (Xiao et al., 2006; Zimnicki et al., 2021). The PU III sample with a high water retention capacity (77.72%) and a high SRC lactic acid (102.74%) is suitable for doughs requiring high hydration and elasticity. The high SRC Na_2CO_3 (112.46%) indicates considerable starch damage which, if controlled, could promote fermentation (Kweon et al., 2011; Xiao et al., 2006; Duyvejonck et al., 2011).

4. Conclusions

The comparative analysis of wheat samples C, PU I, PU II and PU III revealed remarkable differences in morphological, chemical and techno-functional properties relevant for applications in the food industry. PU I had a high starch content, indicating good milling and flour performance. PU II exhibited favourable properties, including a balanced starch and protein content, strong gluten potential and good water and oil absorption, making it suitable for baked goods and dough-based products. PU III, with lower starch and higher lipid content, may be more suitable for formulations requiring improved mouthfeel and lipid binding capacity. Sample C, which served as a control, showed constant but moderate values for all parameters. The results underline the value of initial multiplied seeds not only in crop production but also in supporting specific functional requirements in cereal-based food systems. These results indicate that selected wheat varieties, in particular PU II and PU I, have promising properties for targeted food applications and could serve as valuable candidates for further breeding or industrial-scale use.

Declaration of competing interests

There is no conflict of interest.

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