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The Baking Quality of Wheat Flour (*Triticum aestivum* L.) Obtained from Wheat Grains Cultivated in Various Farming Systems (Organic vs. Integrated vs. Conventional)

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Abstract: The quality of flour is influenced by various factors including genotype, environmental and agronomic conditions, post-harvest grain storage, and milling technology. Currently, the EU focuses on reducing mineral fertilization and promoting less intensive agrotechnology (organic and integrated farming). This research aimed to assess the baking value of flour obtained from four spring wheat cultivars cultivated in three farming systems: organic (ORG), integrated (INT), and conventional (CONV). The wheat grains were sourced from a three-year field experiment (2019–2021) conducted at IUNG-PIB in Pulawy, Poland. Results indicate that the CONV generally yielded more favourable qualitative parameters for the flour, including significantly higher protein content, wet gluten, falling number, and farinographic characteristics such as dough development, stability time, and quality number. Nevertheless, most flours from the ORG system met the quality requirements for the baking industry, showing adequate protein content, wet gluten, and falling number. However, flours from the INT system stood out due to significantly higher water absorption, resulting in increased dough and bread yield. Additionally, bread baked from these flours exhibited a significantly higher bread volume. In sensory evaluation, bread from CONV flours received the highest scores, although the differences in the overall acceptability were not significant.

Keywords: protein content; wet gluten; falling number; water absorption; rheological properties of dough; wheat bread; texture profile analysis; sensory evaluation

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1. Introduction

For centuries, cereal products have been a basic component of the human diet [1]. One of the most important cereal crops is wheat [2,3], and the most frequently cultivated species in the world is common wheat (*Triticum aestivum* L.), also known as bread wheat [4].

Due to its production potential and technological value, wheat plays a special role in the world economy [5]. In 2021, the world wheat cultivation area amounted to 770.9 million ha, and the harvest was 220.8 million tons [3], about 60% of which was intended for processing for consumption purposes [6]. In Europe, the area under wheat cultivation and harvest in 2021 amounted to 269.2 million ha and 62.8 million tonnes, respectively [3].

Since the domestication of wheat (approximately 10,000 years ago), wheat has played a crucial role in global food security. Currently, wheat-based food products contribute approximately 20% of the energy and protein supplied with food to the world population [4].

The main direction of use of wheat grain is milling into flour, which is a raw material to produce confectionery products, pasta and, mainly, bread [4,7]. Bread is one of the most popular food products around the world, including in Europe, where there is a long tradition of baking wheat bread [7,8].

Many factors influence the baking potential of wheat flour. The quality of flour, which is a derivative of the characteristics of the grain used for milling, depends on the genotype (cultivar) and the habitat and agrotechnical conditions during cultivation [9–11]. The baking value of flour is also influenced by the conditions of grain storage after harvesting, the milling technology and the flour storage conditions [12,13]. Among the agrotechnical factors, nitrogen fertilization is one of particular importance, as it influences the quantity and quality of proteins, including gluten proteins, as indicated by the results of many studies [11,14–17]. Wheat flour combined with water creates a dough with unique viscoelastic properties, which distinguishes it from flours obtained from grains of other types of cereals. The rheological properties of wheat dough largely depend on the content and quality of protein, and, more precisely, the structure of gluten, which is formed from the combination of gliadin and glutenin after adding water [15,18]. These proteins are responsible for the elasticity and extensibility of the dough and for the correct structure of the finished product [14]. The activity of amylolytic enzymes also plays a key role in shaping the baking value of flour. Weather conditions have a particular impact on amylolytic activity, especially the amount of rainfall during grain ripening and harvesting [11,19,20].

This research aims to determine the baking value of flour obtained from milling grains of four spring cultivars of common wheat grown in three farming systems with different agrotechnology. The number of scientific publications on this subject is relatively low. The research hypothesis assumed that by using less intensive agrotechnology in wheat production, it is possible to obtain flour of appropriate baking value, meeting the requirements of the baking industry, which guarantees obtaining bread of the desired consumer quality.

2. Materials and Methods

2.1. Research Material

The research material consisted of flour obtained from the milling grain of four spring wheat cultivars: Harenda, Kandela, Mandaryna, and Serenada, grown in three farming systems: organic (ORG), integrated (INT), and conventional (CONV) at the Institute of Soil Science and Plant Cultivation—State Institute Research Center in Pulawy (Poland) in 2019–2021. The detailed methodology of the field experiment, along with a description of the meteorological conditions during the vegetation period, was provided in a previous publication [21].

2.2. Grain Milling

Before milling, the wheat grain was cleaned in a granotetest (Brabender, Duisburg, Germany). Grain samples weighing 2.0 kg were moistened to a moisture content of 13 ± 0.1% and then left for 24 h to equalize the moisture content throughout the grain mass. The grain prepared in this way was milled in a two-lane Quadrumat Senior mill (Brabender Instruments, Germany) in accordance to AACC Method No. 26-50.01 [22]. After milling, a milling balance was prepared, and then flour mixtures with 70% extract were prepared, packed and stored in paper bags. The analyses began two weeks after milling (after the flour ripening process).

2.3. Flour Quality Assessment

Total ash content (AC) was determined according to AACC 08-01.01 [22], total protein content (PC) was determined using the Kjeldahl method (conversion factor N x 5.83) in a Kjeltec 8200 device (Foss, Hillerød, Sweden) according to AACC 46-11.02 [22], wet gluten (WG) and gluten index (GI) were determined in a Glutomatic 2200 device (Perten Instruments, Hägersten, Sweden) according to AACC 38-12.02 [22], and falling number (FN) was determined using the Hagberg method—Perten in Falling Number 1400 (Perten Instruments, Hägersten, Sweden) in accordance with AACC 56-81.03 [22].

2.4. Dough Rheological Measurements

Water absorption and dough rheological parameters were determined using a Farinograph-E model 810114 equipped with a 50 g flour mixer (Brabender Gmbh & Co., Ltd. KG, Duisburg, Germany) according to the AACC 54-21 method [22]. The water absorption of flour was determined based on the amount of water needed to obtain a dough with a consistency of 500 FU, and the rheological parameters of the dough (development time, stability time, softening after 10 min of mixing, and quality number) were determined in the Farinograph v.4.2.1 program.

2.5. Bread Baking and Characteristics of Bread

The dough recipe consisted of 500 g of wheat flour, 15.0 g of yeast (Lesaffre Polska S.A., Wolczyn, Poland), 7.5 g of table salt (Klodawa S.A., Klodawa, Poland), and water in the amount needed to obtain a dough with a consistency of 350 FU. The amount of water was calculated based on the farinographic water absorption of flour. All ingredients were mixed using an SP-800A mixer (Spar Food Machinery, Taiwan) for 4 min at speed 2. The dough was transferred to the D-32 fermenter (Sveba Dahlen, Fristad, Sweden). The total fermentation time was 90 min. After 60 min, the dough was punctured to aerate and remove the produced gases. Then, 3 pieces of dough were weighed, 250 g each. The dough pieces were manually formed, placed in molds, and left for final proofing in the fermentation chamber for 30 min. Baking was conducted in an electric oven (DC-32E, Sveba Dahlen, Fristad, Sweden) at a temperature of 230 °C for 30 min. After baking, the breads were left to cool. After cooling, the breads were weighed, covered with foil, and stored at room conditions for 24 h. The total baking losses were calculated [23], the volume of bread was determined using a Sa-Wa volume meter (Sadkiewicz Instruments, Bydgoszcz, Poland) in accordance with the AACC method 10-05.01 [22], and then converted into 100 g of bread. The crumb properties were also determined: crumb porosity index based on the Dallmann scale, crumb density, and dough and bread yield were calculated according to the methodology provided by Jańczak-Pieniązek et al. [9] and Bot et al. [24].

2.6. Bread Texture

The texture profile analysis of bread crumbs was determined using the TPA (Texture Profile Analysis) method using Texture analyser type TA.XT2i (Stable Microsystem, Surrey, UK) according to the methodology provided by Armero and Collar [25]. Samples with a diameter of 50 mm were cut from 20 mm thick bread slices and then placed on the measuring table of the device and compressed twice with a cylindrical head with a diameter of 25 mm. The head travel speed was 1 mm min^{-1} and the time between subsequent compressions was 45 s. From the obtained curves, resilience, springiness, and hardness were determined in the Texture Expert Exceed v. 1.00 computer software.

2.7. Sensory Evaluation of Bread

A 9-point hedonic scale was used for the sensory assessment of bread, with scores ranging from −4 (do not like it very much) to 4 (like it very much) [26]. The assessment considered the external appearance of the loaf, smell, taste, crust colour, colour and porosity of the crumb. Then, the overall acceptability was determined. The bread samples were assessed by forty-five panelists (women and men aged 20 to 56) in a room with daylight and a temperature of 20 °C.

2.8. Statistical Analysis

In order to compare the influence on all study traits, cultivar ($n = 4$), farming system ($n = 3$), growing season ($n = 3$), and their interaction effects, a three-way analysis of variance ANOVA was used. The significant of means differences for study factors were evaluated using Tukey's test. The assumption of normality of the layouts was checked using the QQ Plots for residuals and the homogeneity of variances using the Levene's test. All study traits meet the above assumptions for the ANOVA and Tukey test. We used principal component analysis (PCA) to determine the relationship between study traits and between the combination of cultivars and farming systems. All statistical analyses were conducted at the significance level of $\alpha = 0.05$ and use R 3.4.2.

3. Results and Discussion

3.1. Flour Quality Assessment

Ash Content (AC) in the tested flours was significantly influenced by the year of grain harvest and the genotype (cultivar) (Table 1). Interactions between the tested cultivar and the farming system were also indicated, and are presented in the Supplement File (Figure S1a). Flours obtained from grain harvested in 2020 and 2021 had the highest AC content (mean 0.76 and 0.73% d.m., respectively), the lowest in 2019 (mean 0.65% d.m.). However, Jaskulska et al. [23] and Cacak-Pietrzak [27] did not show such relationships. The AC content in flours from grains of various wheat cultivars ranged from 0.66% d.m. (Harenda cultivar) up to 0.79% d.m. (Serenada cultivar). Differences in the AC content in flour are also indicated by other authors [9,28–31]. Our research did not indicate a significant impact of the farming system on the AC content; however, flours from CONV grain were characterized by the highest ash content. Nevertheless, research by Draghici et al. [32] and Toader et al. [33] indicate a higher AC content in flour obtained from grain from ORG. Flours obtained from spring wheat grains generally contain more ash than flour from winter wheat [34], which is due to the smaller size of the grains and poorer proportions between the endosperm and the pericarp and seed coat, which contains the most minerals [35]. In Poland, based on the ash content, wheat flour is classified into types [36], on the basis of which their purpose is determined. Minerals are nutritionally important ingredients [37]; however, the oversupply of them causes darkening of the colour and poorer baking value of the flour [31].

Table 1. Quality parameters of flour depending on the harvest year, cultivar, and farming system.

Source of Variation	AC [% d.m.]	PC [% d.m.]	WG [%]	GI [—]	FN [s]
Year	**	**	**	**	**
2019	0.65 ± 0.03 ^{a}	13.0 ± 1.72 ^{a}	28.7 ± 4.48 ^{a}	99 ± 0.86 ^{c}	290 ± 70.95 ^{a}
2020	0.76 ± 0.06 ^{b}	13.2 ± 1.46 ^{ab}	31.8 ± 3.89 ^{b}	95 ± 2.84 ^{a}	505 ± 50.55 ^{b}
2021	0.73 ± 0.06 ^{b}	13.7 ± 1.33 ^{b}	32.1 ± 4.45 ^{b}	97 ± 1.39 ^{b}	309 ± 59.68 ^{a}
Cultivar	**	**	**	**	**
Harenda	0.66 ± 0.04 ^{a}	13.0 ± 1.28 ^{a}	29.0 ± 4.14 ^{a}	99 ± 1.34 ^{c}	326 ± 102.39 ^{a}
Kandela	0.70 ± 0.06 ^{ab}	12.9 ± 1.35 ^{a}	29.5 ± 4.07 ^{a}	97 ± 2.48 ^{ab}	329 ± 107.91 ^{a}
Mandaryna	0.69 ± 0.04 ^{ab}	13.0 ± 1.70 ^{a}	30.5 ± 3.79 ^{a}	96 ± 2.81 ^{a}	390 ± 118.74 ^{b}
Serenada	0.79 ± 0.07 ^{b}	14.3 ± 1.37 ^{b}	34.4 ± 4.19 ^{b}	97 ± 3.14 ^{ab}	426 ± 101.72 ^{c}
Farming system	**n.s.**	**	**	**n.s.**	**
ORG	0.71 ± 0.70 ^{a}	12.2 ± 1.35 ^{a}	28.6 ± 4.5 ^{a}	97 ± 3.0 ^{a}	349 ± 130.21 ^{a}
INT	0.70 ± 0.08 ^{a}	13.2 ± 1.35 ^{b}	30.4 ± 3.67 ^{b}	97 ± 2.59 ^{a}	355 ± 98.02 ^{a}
CONV	0.72 ± 0.07 ^{a}	14.5 ± 0.91 ^{c}	33.6 ± 3.85 ^{c}	97 ± 2.31 ^{a}	399 ± 110.35 ^{b}

Data are reported as means ± standard deviations; abbreviations: n.s.—not significant, **—significant (different letters on the top of data: $^{a, b, c}$ are significantly different at $\alpha = 0.05$) between means according to Tukey's test. Abbreviations: AC—ash content; PC—protein content; WG—wet gluten; GI—gluten index; FN—falling number; ORG—organic; INT—integrated; CONV—conventional.

Protein Content (PC) in the tested flours depended significantly on the year of grain harvest, genotype (cultivar), and the farming system used during cultivation (Table 1). Flours from grain harvested in 2021 had the highest PC content (mean 13.7% d.m.), which may be related to meteorological conditions favouring the accumulation of nitrogen in the plant (warm and humid April) and the deposition of protein substances in the wheat grain (warm June) [21]. Grain flour from the 2019 harvest contained the least PC. The content of this ingredient was lower by 0.7 p.p. than in flours from 2021 and by 0.5 p.p. lower than in flours from 2020. Similar relationships were found for the protein content in the grain from which the tested flours were obtained [21]. Finlay et al. [29] also indicated the significant impact of meteorological conditions on the protein content in flour.

Own research also showed cultivar differences in the PC in flours, which ranged from 12.9–14.3% d.m. Flours from the Serenada cultivar had the significantly highest total PC. In flours from other wheat cultivars, the PC content was similar (means 12.9–13.0% d.m.). Cultivar differences in PC are also indicated by other authors [11,31,37,38]. A significant impact of the farming system on PC was also found in this research. The use of intensive production, as indicated in the literature, increases the PC in wheat grain [21,27,37,39–42], and thus in the final product, which is flour [27,32]. Flours obtained from grain from CONV had the significantly highest PC (mean 14.5% d.m.); it was higher by 2.3 p.p. than in flours from ORG and by 1.3 p.p. than in flours from INT. The lower PC in ORG flour results from the lower absorption of nitrogen from organic fertilizers approved for use in this farming system [31].

There are no applicable standards regarding the minimum protein content in flour intended for baking bread; however, a high content of this ingredient is desirable (13–14%), which translates into a high content of gluten proteins [43].

Wet Gluten (WG) determined in the flours tested depended significantly on the year of grain harvest, the genotype (cultivar) and the crop production system used (Table 1). Flours from grain from the 2021 and 2020 harvests had the highest WG (means: 32.1 and 31.8%, respectively) and were significantly higher than the WG leached from flours from the 2019 harvest (mean 28.7%) by 3.4 p.p. and 3.1 p.p., respectively. The significant influence of meteorological conditions on WG in wheat flour is also indicated by Jaskulska et al. [23]. In our study, WG also depended on cultivar characteristics. The significantly highest WG was characterised by flours from milling grain of the Serenada cultivar (mean 34.4%), while WG from flours from grain of other wheat cultivars was at a similar level (means 29.0–30.5%). Cultivar dependencies on WG are also indicated by the literature data [9,11,31,37,44]. WG was also significantly affected by the farming system used in the crop. The highest significantly WG was characterised by flour from CONV grain (mean 33.6%), while the lowest was from ORG (mean 28.6%). WG was positively correlated with PC content (r = 0.87, Figure 1). Similar correlations are also indicated by Rozbicki et al. [11] and Ionescu et al. [45].

The wet gluten (WG) is one of the most important factors in determining the baking suitability of wheat flour; higher WG indicates better quality of flour for breadmaking [44,46]. According to PN-A-74022 [36], in flour intended for bread baking, the WG should not be lower than 25%. These requirements were not met by only three samples of flour from Harenda (22.8%), Kandela (21.4%), and Mandaryna (24.3%) cultivars grown in 2019 in ORG system (Table S1).

The Gluten Index (GI) values of the flours tested were significantly influenced by the year of grain harvest and genotype (cultivar) (Table 1). The value of this parameter was significantly highest for flours from grain harvested in 2019 (mean 99). The lowest GI value was characterised by flours from grain from the year 2020 (mean 95). The influence of meteorological conditions on GI is also indicated by Linina and Ruža [20] and Sobolewska and Stankowski [37]. Among the wheat cultivars tested, flours from the grain of the cultivar Harenda (mean 99) were characterised by the highest GI, while flours from the grain of the cultivar Mandaryna (mean 96) were characterised by the lowest GI. Cultivar variation in GI is also indicated by Rozbicki et al. [11], Feledyn-Szewczyk et al. [31], and Sobolewska and Stankowski [37]. However, in our study, no significant effect of the farming system on the value of this parameter was found. On the other hand, in the study of Draghici et al. [32], higher GI values were characterised by flours from grain from ORG than CONV.

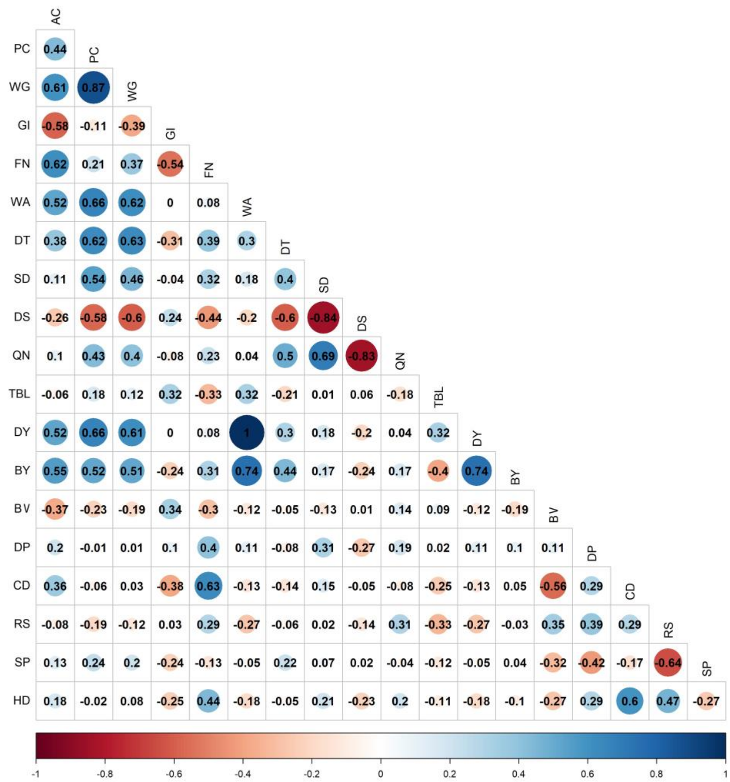

Figure 1. Correlation between all study traits. Abbreviations: AC—ash content; PC—protein content; WG—wet gluten; GI—gluten index; FN—falling number; WA—water absorption; DT—development time; SD—stability; DS—degree of softening; QN—quality number; TBL—total baking loss; DY—dough yield; BY—bread yield; BV—bread volume; DP—Dallman porosity; CD—crumb density; RS—resilience; SP—springiness; HD—hardness.

GI values for wheat flour intended for bread production should be in the range of 60 to 90. GI values above 90 indicate gluten that is too strong, and below 60 indicates too weak gluten, which can result in bakery products of inferior quality [47]. In our study, most of the flours were characterised by a GI above 95. Only the sample of flour from the Serenada cultivated in INT in 2020 was characterised by a GI value in the range 60–90 (Table S1).

Falling Number (FN) values depended significantly on the year of grain harvest, genotype (cultivar), and farming system (Table 1). The significantly lowest amylolytic enzyme activity (mean 505 s) was found in flours from grain from the 2020 harvest. In flours from grain from the other years of the study, amylolytic enzyme activity was higher (means 290 and 309 s). The influence of meteorological conditions on FN is also indicated by other authors [20,48]. Our research also showed cultivar variation in this parameter. The significantly highest value of FN was characterised by flours from grain of the Serenada cultivar (mean 426 s), slightly lower from the Mandaryna cultivar (mean 390 s). The values of this parameter for flours from grain of the other cultivars (Harenda and Kandela) were similar (means 326 and 329 s). A significant effect of cultivar on FN was also shown by Rozbicki et al. [11], Feledyn-Szewczyk et al. [31], and Draghici et al. [32]. A significant effect of farming system on FN values was also found in this research. Flours from grain from CONV (mean 399 s) had the highest significant FN value. Flours from grain of the other farming systems were characterised by similar FN values (means 349 and 355 s). In a study by Cacak-Pietrzak [27], there was no significant effect of farming system on the activity of amylolytic enzymes in flours from grain from the ORG and CONV systems, while Draghici et al. [32] showed that ORG flours were characterised by high activity of these enzymes (mean FN 90 s). Some authors [49–51] also point to the effect of nitrogen fertilisation and post-harvest grain storage conditions on flour FN. The optimum activity of amylolytic enzymes in flour for breadmaking should be at a medium level (FN in the range 220–280 s). The use of flour with a high enzyme activity (FN below 150 s) for baking will result in a small volume and a flaky crust, while bread baked from flour with too low enzyme activity (FN above 300 s) has a compact crumb, showing a tendency to crumble and a spherical shape [48,52].

Not all of the flours tested met the quality requirements for the FN parameter. The values of this parameter ranged from 185–599 s. The lowest FN, and thus the highest amylolytic enzyme activity, was characterised by flour from wheat grain of the Mandaryna cultivar grown in ORG in 2019 (185 s, Table S1). In contrast, the highest FN was obtained for flour from wheat grain of the Serenada cultivar from ORG harvested in 2020 (599 s, Table S1). At the same time, flours from grain of this wheat cultivar, irrespective of the year of grain harvest and plant farming system, were characterised by low amylolytic enzyme activity (FN $\geq$ 300 s).

3.2. The Water Absorption and Rheological Properties

Water Absorption (WA) of the flours tested was significantly dependent on grain year, genotype (cultivar), and farming system (Table 2). Interactions between the cultivar grown and the farming system are also shown (Figure S2a). Flours from grain from the 2021 harvest (mean 58.2%), which at the same time had the highest PC content, had the significantly highest WA, while flours from grain from 2020 (mean 56.4%) with the lowest PC content had the significantly lowest WA (Table 1). The significant influence of meteorological conditions on the WA parameter is also indicated by the study of Sobolewska et al. [6] conducted on whole wheat flour. In our study, flours from grain of the Serenada cultivar had the significantly highest WA (mean 61.1%), while the mean WA values of flours from grain of the other wheat cultivars ranged from 55.5–56.5%. Cultivar variation in WA is also indicated by the literature data [11,27,53]. WA was also significantly influenced by the farming system used. The significantly lowest WA was characterised by flours from milling grain with ORG (mean 56.5%). The water absorption of flours from INT and CONV was at a similar level (mean, respectively 57.8 and 57.5%). The higher water absorption of flour from grain from CONV is also indicated by the results of Cacak-Pietrzak [27] and Sobolewska and Stankowski [37]. WA of flour is influenced by many factors including PC content, the quantity and quality of gluten proteins (WG, GI), amylolytic enzyme activity (FN), and AC [47,48,53]. In our study, positive correlations were found between WA and PC (r = 0.66), WG (r = 0.62) and AC (r = 0.52), as shown in Figure 1. Similar correlations were also shown by Sobolewska et al. [6].

From a technological point of view, a high water absorption of the flour is desirable, which determines a higher DY and BY, which in turn translates into higher economic returns for the bakery [54]. According to Serna-Saldivar [55], wheat flours for baking purposes should be characterised by a WA above 58%. The WA of the flour samples tested ranged from 53.2–63.8% (Table S2). The most favourable WA values, were characterised by flours from grain of the Serenada cultivar, with the exception of the 2019 sample from ORG (mean 57.8%, Table S2). The WA of flours from grain of the other wheat cultivars ranged from 53.2–59.5%. WA values above 58.0% were obtained for wheat grain flour grown in 2021 in INT and CONV; WA above 58% was also characterised by flour from grain of the Mandaryna cultivar from INT in 2019 (59.5%, Table S2).

Development Time (DT) depended significantly on harvest year, cultivar (genotype) and farming system (Table 2). Interactions between cultivar and farming system were also shown (Figure S2b). Indeed, the longest DTs were obtained for dough made of flour from grain from the harvest in 2020 (mean 4.2 min), while the shortest were obtained for samples from 2021 (mean 3.0 min). A significant influence of meteorological conditions on DT is also indicated by Sobolewska and Stankowski [37], while Cacak-Pietrzak [27] shows no such relationship. Among the studied wheat cultivars, the longest DT was significantly characterised by doughs made of flour from grain of the cultivars Mandaryna (mean 4.3 min) and Serenada (mean 4.2 min), while the shortest from the cultivar Harenda (mean 2.3 min). Similar correlations were also shown by Jańczak-Pieniążek et al. [9] and Cacak-

Pietrzak [27], while in the study by Sobolewska and Stankowski [37] there was no cultivar differentiation with respect to this parameter. A significant effect of farming system on DT was also found in our study. Significantly the longest DT was characterised by trials from CONV (mean 4.9 min) and the shortest from the ORG system (mean 2.6 min). Similar correlations were shown by Cacak-Pietrzak [27] and Sobolewska and Stankowski [37]. Cacak-Pietrzak [27] and Nikolic et al. [56] indicate that the properties of wheat dough, including DT, are highly dependent on the amount and quality of protein. This is also confirmed by our research. DT was positively correlated with parameters such as PC (r = 0.62) and WG (r = 0.63), as shown in Figure 1.

Table 2. The water absorption of flour and rheological properties of wheat dough depending on the harvest year, cultivar, and farming system.

Source of Variation	WA [%]	Properties of Dough			
		DT [min]	SD [min]	DS [FU]	QN [—]
Year	**	**	**	**	**
2019	57.2 ± 2.12 ^{b}	3.5 ± 2.23 ^{ab}	12.0 ± 6.06 ^{b}	35 ± 21.77 ^{b}	93 ± 42.25 ^{b}
2020	56.4 ± 3.46 ^{a}	4.2 ± 2.25 ^{b}	12.4 ± 4.90 ^{b}	28 ± 15.78 ^{a}	97 ± 55.53 ^{c}
2021	58.2 ± 2.67 ^{c}	3.0 ± 1.19 ^{a}	9.5 ± 4.80 ^{a}	41 ± 21.10 ^{c}	82 ± 40.16 ^{a}
Cultivar	**	**	**	**	**
Harenda	56.5 ± 1.17 ^{b}	2.3 ± 0.56 ^{a}	10.5 ± 7.17 ^{a}	48 ± 23.72 ^{b}	69 ± 52.68 ^{a}
Kandela	55.5 ± 1.67 ^{a}	3.5 ± 1.58 ^{b}	10.0 ± 4.76 ^{a}	37 ± 22.55 ^{b}	90 ± 36.95 ^{b}
Mandaryna	55.9 ± 2.36 ^{a}	4.3 ± 2.81 ^{c}	12.3 ± 5.24 ^{b}	27 ± 16.56 ^{a}	112 ± 50.17 ^{c}
Serenada	61.1 ± 1.77 ^{c}	4.2 ± 1.78 ^{c}	12.6 ± 3.71 ^{b}	27 ± 8.34 ^{a}	92 ± 36.90 ^{b}
Farming system	**	**	**	**	**
ORG	56.5 ± 3.07 ^{a}	2.6 ± 1.25 ^{a}	9.6 ± 5.54 ^{a}	45 ± 21.70 ^{b}	64 ± 41.33 ^{a}
INT	57.8 ± 2.88 ^{b}	3.2 ± 1.99 ^{b}	9.3 ± 4.73 ^{a}	40 ± 18.24 ^{b}	81 ± 37.07 ^{b}
CONV	57.5 ± 2.56 ^{ab}	4.9 ± 1.95 ^{c}	15.1 ± 3.72 ^{b}	20 ± 10.47 ^{a}	128 ± 34.95 ^{c}

Data are reported as means ± standard deviations; abbreviations: **—significant (different letters on the top of data: $^{a, b, c}$ are significantly different at α = 0.05) between means according to Tukey's test. Abbreviations: WA—water absorption; DT—development time; SD—stability of dough; DS—degree of softening; QN—quality number; ORG—organic; INT—integrated; CONV—conventional.

According to the classification given by Serna-Saldivar [55], very strong wheat flour is characterised by a DT longer than 10 min, which is not desirable from a technological point of view. The DT of none of the flours tested exceeded this value. The longest DT was characterised by the dough made from flour from Mandaryna cultivar grown in CONV in 2019 (8.2 min), while the shortest was made from flour from Kandela cultivar grown in ORG in 2019 (1.6 min, Table S2).

Stability of dough (SD) depended significantly on the year of grain harvest, genotype (cultivar), and farming system (Table 2). The longest SD was characterised by the dough of flour from grain harvested in 2020 (mean 12.4 min), it was significantly longer compared to samples from 2021 by 28.6%. The variation in SD depending on the year of grain harvest was also shown by Cacak-Pietrzak [27] and Sobolewska and Stankowski [37]. In our study, the longest SD was found for dough made from flour from grain of the Serenada and Mandaryna cultivars (mean 12.6 and 12.3 min, respectively). The significantly lowest SD was found for dough made from grain flour of the Kandela cultivar (mean 10.0 min). Cultivar variation in SD is also indicated by the literature data [27,37]. In the present study, the longest SD was significantly characterised by flour from grain from CONV (mean 15.1 min). The value of this parameter was 38.4% higher compared to samples from INT and 36.4% higher than samples from ORG. A significant effect of the farming system on SD is also indicated by Sobolewska et al. [37]. In a study by Cacak-Pietrzak [27], longer SD was characterised by trials with CONV than ORG, but these differences were not statistically significant. In our study, SD was positively correlated with PC (r = 0.54) and WG (r = 0.46), as shown in Figure 1. Similar correlations were also shown by Rozbicki et al. [11] and Sobolewska and Stankowski [37].

According to the classification given by Szafrańska [57], based on the mean SD values, flours from grain from the 2019 and 2020 harvests were classified as flours of very good quality (SD above 10 min), while those from 2021 were classified as flours of good baking quality (SD 7–10 min). According to this classification, not all of the flours tested met the requirements for bread flours with respect to the SD parameter. SD values ranged from 2.4–19.0 min (Table S2). In general, the SDs of the flours obtained from wheat grain grown in CONV were above 10 min, except for flour from milling grain of the Harenda cultivar from the 2021 harvest (mean 7.3 min, Table S2). Flours from wheat grain grown in INT and ORG generally had a lower SD (range mean 3.5–18.6 and 2.4–17.8 min, respectively, Table S2).

Degree of Softening (DS) depended significantly on harvest year, genotype (cultivar) and farming system (Table 2). Interactions were also found between cultivar and farming system (Figure S2d). The significantly lowest DS was noted for dough made from grain flour from the 2020 harvest (mean 28 FU), while the highest value of this parameter was characterised by dough made from grain flour from the 2021 harvest (mean 41 FU). A significant effect of cultivar on DS was also found. Indeed, the lowest DS value was characterised by doughs from grain flour of the cultivars Mandaryna and Serenada (mean 27 FU), while the highest was from the cultivar Harenda (mean 48 FU). Cultivar variation in DS is also indicated by Jańczak-Pieniążek et al. [9]. Significantly the lowest DS value in the present study was characterised by doughs from grain flour from CONV (mean 20 FU), while the highest value was from grain flour from ORG (mean 45 FU). DS was shown to be negatively correlated with parameters such as PC (r = −0.60), WG (r = −0.58), DT (r = −0.60) and SD (r = −0.84), as shown in Figure 1. Similar relationships were also shown by Rozbicki et al. [11].

DS indicates a decrease in dough consistency during mixing, which depends on the amount and quality of gluten in the flour and determines the structure of the dough and its resistance to mixing [58]. According to Szafrańska [57], the softening of wheat dough should be in the range of 0 to 30 FU. This requirement was met by most of the grain flours from CONV, except for the Harenda flour from the harvest in 2021 (mean 45 FU, Table S2). Reducing the intensity of the cultivation level generally resulted in a deterioration of the DS parameter, but no less, flours meeting the above quality requirements were also obtained from grain from the ORG system.

Quality Number (QN) depended significantly on the year of grain harvest, genotype (cultivar) and farming system (Table 2). Interactions between cultivar and farming system were also shown (Figure S2e). Indeed, the highest and most favourable QN values were characterised by flours from grain from the 2020 harvest (mean 97), while the lowest were from the 2021 harvest (mean 82). The influence of meteorological conditions on QN is also indicated by Cacak-Pietrzak [27]. Cultivar differentiation of this parameter was also shown. Among the tested wheat cultivars, the highest QN value was significantly characterised by flours from grain of the Mandaryna cultivar (mean 112), while the lowest flours from grain of the Harenda cultivar (mean 62). Cultivar variation is also indicated in the literature [9,27]. In our study, flours from grain of the cultivars Kandela and Serenada were characterised by similar QN values (mean 90 and 92, respectively). QN was also significantly influenced by the farming system. Significantly the highest QN values were characterised by flours from CONV (mean 128), while for samples from ORG the values of this parameter were half as high (mean 64). The effect of agrotechnology intensity on QN was also indicated by Jańczak-Pieniążek et al. [9].

The flour quality number is a measure of the rheological properties of the dough obtained from it. Values of the parameter above 100 are characteristic of highly elastic dough [58]. In our study, flours from CONV were generally characterised by a QN above 100, except for dough from flours of the Harenda cultivar from the 2021 and 2019 harvests (65 and 92 FU, respectively, Table S2). Nevertheless, doughs with a QN above 100 were also obtained from ORG flour (Mandaryna cultivar from 2020, Table S2). In contrast, doughs made from flour from grain from INT were characterised by a more favourable QN than ORG, but generally lower quality than CONV.

3.3. Baking Process Parameters and Quality Indicators of Wheat Bread

Total bread losses (TBL) depended significantly on the year of grain harvest, genotype (cultivar) and farming system (Table 3). The significantly lowest TBL was found for bread loaves obtained from flour from grain harvested in 2020 (mean 12.3%), and was 1.5 and 1.2 p.p lower than the TBL obtained for the 2021 and 2019 samples, respectively. The lowest TBL was characterised by bread baked from flour obtained from grain of the Mandaryna cultivar (mean 12.7%), while the highest was from the Serenada cultivar (mean 13.8%). The influence of the cultivar factor on TBL is also indicated by Sobolewska and Jaroszewska [59]. TBL in our study was also significantly influenced by the farming system. The significantly highest TBL was characterised by bread obtained from flour made from grain with CONV (mean 13.4%). Sobolewska and Jaroszewska [59] also found significantly higher TBL for bread baked from flour obtained from the conventional system.

Table 3. Baking process parameters and quality indicators of bread depending on the harvest year, cultivar, and farming system.

Source of Variation	TBL [%]	DY [%]	BY [%]	BV [cm^3 100 g^{-1}]
Year	**	**	**	**
2019	13.5 ± 1.12 ^{b}	157.2 ± 2.12 ^{ab}	136.0 ± 2.46 ^{a}	376.7± 16.11 ^{b}
2020	12.3 ± 0.85 ^{a}	156.4 ± 3.46 ^{a}	137.1 ± 2.81 ^{b}	357.3 ± 15.91 ^{a}
2021	13.8 ± 0.98 ^{b}	158.2 ± 2,67 ^{b}	136.4 ± 2.38 ^{ab}	355.0 ± 12.95 ^{a}
Cultivar	**	**	**	**
Harenda	13.0 ± 1.14 ^{a}	156.5 ± 1.17 ^{b}	136.1 ± 1.44 ^{b}	364.9 ± 12.96 ^{b}
Kandela	13.3 ± 1.06 ^{ab}	155.5 ± 1.67 ^{a}	134.9 ± 1.42 ^{a}	358.4 ± 11.17 ^{a}
Mandaryna	12.7 ± 1.04 ^{a}	155.9 ± 2.36 ^{a}	136.1 ± 2.92 ^{b}	365.9 ± 24.03 ^{b}
Serenada	13.8 ± 1.19 ^{ab}	161.1 ± 1.77 ^{c}	138.9 ± 2.36 ^{c}	362.9 ± 19.65 ^{ab}
Farming system	**	**	**	**
ORG	13.2 ± 1.03 ^{a}	156.5 ± 3.07 ^{a}	135.9 ± 2.43 ^{a}	361.7 ± 19.28 ^{a}
INT	13.1 ± 1.16 ^{a}	157.8 ± 2.88 ^{b}	137.2 ± 2.80 ^{b}	366.4 ± 16.96 ^{b}
CONV	13.4 ± 1.28 ^{b}	157.5 ± 2.56 ^{b}	136.5 ± 2.40 ^{ab}	360.9 ± 17.20 ^{a}

Data are presented as means ± standard deviations; **—significant (different letters on the top of data: $^{a, b, c}$ are significantly different at α = 0.05) between means according to Tukey's test. Abbreviations: TBL—total bread losses; DY—dough yield; BY—bread yield; BV—bread volume; ORG—organic; INT—integrated; CONV—conventional.

TBL indicates the weight loss during the baking and cooling process of the bread. The value of this parameter depends on the amount of water and volatile substances lost: CO_2, alcohol, and volatile acids. From the point of view of baking technology, this is a loss that should be minimised [60]. The total bread losses of the bread obtained ranged from 11.1 to 14.9% (Table S3). The lowest values of TBL were generally characterised by bread baked from flour from Mandaryna and Harenda cultivars, while bread baked from flour of the Serenada cultivar had the least favourable values of this parameter (Table S3)

Dough yield (DY) depended significantly on grain year, genotype (cultivar), and farming system (Table 3). Interactions between cultivar and the farming system used are also shown (Figure S3b). The highest DY (mean 158.2%) was obtained from flour from grain from the 2021 harvest, while in the other years it was at a similar level (means 157.2 and 156.4%). Indeed, the highest DY was obtained from flour of the Serenada cultivar (mean 161.1%) compared to the other cultivars. The lowest DY was obtained from flours of the cultivars Kandela (mean 155.5%) and Mandaryna (mean 155.9%). The effect of cultivar factor on DY is also indicated by Jańczak-Pieniążek et al. [9]. The significantly lowest DY was obtained from flour from grain from INT (mean 156.5%). DY from ORG and CONV was at a comparable level (means 157.5 and 157.8%, respectively). Positive correlations were found between DY and AC (r = 0.52), PC (r = 0.66), and WG (r = 0.61), as shown in Figure 1.

DY is the amount of dough obtained from 100 kg of flour. From an economic point of view, the higher the DY, the more profitable the bread production [61]. The highest DY was obtained from flour from grain of Serenada cultivar grown in CONV in 2021 (163.2%, Table S3).

Bread Yield (BY) depended significantly on the year of grain harvest, genotype, and farming system (Table 3). The highest BY was obtained from flours from grain harvested in 2020 (mean 137.1%), and it was significantly higher compared to samples from 2019 (mean 136.0%). In contrast, Cacak Pietrzak [27] showed no significant effect of meteorological conditions on the BY parameter. In the present study, the significantly highest BY was obtained from flour of the Serenada cultivar (mean 138.9%), and the significantly lowest from flour of the Kandela cultivar (mean 134.9%). Cultivar variation in BY is also indicated by Cacak-Pietrzak [27], while Sobolewska and Jaroszewska [59] show no significant effect of cultivar on BY. In our study, significantly higher BY was obtained from flour from grain from INT (mean 137.2%) compared to ORG (mean 135.9%). In contrast, in a study by Cacak-Pietrzak [27], no significant effect of farming system on BY was found. In our study, positive correlations were found between BY and parameters such as AC (r = 0.55), PC (r = 0.52), WG (r =0.51), WA (r = 0.74), and DY (r = 0.74), as shown in Figure 1.

Bread yield is the ratio of the weight of bread produced to the amount of flour used in production, expressed as a percentage [61]. The higher the BY value, the more economically viable the production. The highest BY was generally obtained from flour from grain of the Serenada cultivar, regardless of the farming system used (Table S3).

Bread Volume (BV) depended significantly on the year of grain harvest, the genotype (cultivar), and the farming system used (Table 3). The influence of meteorological conditions on BV is also indicated by Cacak-Pietrzak [27]. In our study, the highest BV was characterised by bread baked from flour of the Mandaryna cultivar (mean 365.9 cm^3 100 g^{-1}), but significant differences in the values of this parameter were found only for bread baked from flour of the Kandela cultivar and bread baked from flour of the Mandaryna and Harenda cultivars. A significant effect of genotype on BV was also proved by Cacak-Pietrzak [27] and Feledyn-Szewczyk et al. [31]. In our study, the significantly highest BV was characterised by bread baked from INT flour (366.4 cm^3 100 g^{-1}), BV from CONV, and ORG flour was at a similar level (means of 360.9 and 361.7 cm^3 100 g^{-1}), respectively. On the other hand, Cacak-Pietrzak [27] showed no significant effect of farming system on BV. However, studies by Jańczak-Pieniążek et al. [9] indicate an increase in BV when fertilisation intensity is increased.

Volume is an important quality parameter for bread. Loaves of bread with a large volume are perceived as more attractive by consumers. This parameter depends on the type and quality of flour, the raw material composition of the dough, and the technological process used [60]. According to the Polish Standard [62], the volume of bread obtained from low-textured flours should be no less than 230 cm^3 100 g^{-1}. BV of the tested samples was in the range of 333–400 cm^3 100 g^{-1} (Table S3), which confirms that each sample met the above quality requirements.

3.4. Quality Indicators of Bread Crumb

Dallman porosity (DP) of the bread crumb depended significantly on the year of grain harvest, genotype (cultivar), and farming system (Table 4). Interactions were also found between the cultivar and the farming system used (Figure S4a). The highest DP was characterised by the bread crumbs from flour from grain harvest in 2020 (mean 66), the lowest from 2021 (mean 56). The influence of meteorological conditions on DP is also indicated by Cacak-Pietrzak [27]. Indeed, the highest crumb DP was characterised by bakery products made of flour from grain of Serenada cultivar (mean 71); mean values of this parameter for bakery products made of flour of other wheat cultivars were in the range of 56–60. Significant differentiation of DP depending on the cultivar grown is also indicated by other authors [9,27]. Studies by Jańczak-Pieniążek et al. [9] on comparative assessment of the baking quality of hybrid and population wheat cultivars indicate significant differentiation of DP of bread depending on cultivation intensity. In our study, the bread crumbs obtained from flour from CONV flour (mean 64) was significantly characterised by the highest DP.

Table 4. The quality indicators of bread crumb depending on the harvest year, cultivar, and farming system.

Source of Variation	DP [Score]	CD [g $(cm^3)^{-1}$]	RS [—]	SP [—]	HD [N]
Year	**	**	**	**	**
2019	63 ± 13.81 ^{ab}	0.26 ± 0.02 ^{a}	0.34 ± 0.06 ^{b}	0.83 ± 0.22 ^{a}	7.01 ± 1.42 ^{a}
2020	66 ± 7.72 ^{ab}	0.32 ± 0.02 ^{b}	0.43 ± 0.20 ^{c}	0.85 ± 0.23 ^{a}	8.76 ± 1.39 ^{b}
2021	56 ± 12.96 ^{a}	0.28 ±0.02 ^{ab}	0.30 ± 0.03 ^{a}	0.93 ± 0.03 ^{b}	7.58 ± 1.02 ^{a}
Cultivar	**n.s.**	**	**	**	**n.s.**
Harenda	60 ± 12.33 ^{a}	0.30 ± 0.04 ^{b}	0.42 ± 0.22 ^{b}	0.80 ± 0.25 ^{a}	7.91 ± 1.96 ^{a}
Kandela	58 ± 9.62 ^{a}	0.29 ± 0.02 ^{ab}	0.33 ± 0.05 ^{a}	0.92 ± 0.04 ^{b}	7.67 ± 1.00 ^{a}
Mandaryna	56 ± 10.43 ^{a}	0.28 ± 0.04 ^{a}	0.35 ± 0.05 ^{a}	0.95 ± 0.02 ^{b}	7.66 ± 1.32 ^{a}
Serenada	71 ± 12.38 ^{b}	0.29 ± 0.03 ^{ab}	0.33 ± 0.12 ^{a}	0.80 ± 0.25 ^{a}	7.90 ± 1.50 ^{a}
Farming system	**	**n.s.**	**n.s.**	**	**
ORG	61 ± 13.93 ^{a}	0.29 ± 0.03 ^{a}	0.30 ± 0.10 ^{a}	0.87 ± 0.18 ^{ab}	7.44 ± 1.34 ^{a}
INT	59 ± 11.94 ^{a}	0.29 ± 0.03 ^{a}	0.39 ± 0.15 ^{a}	0.85 ± 0.21 ^{a}	7.47 ± 1.50 ^{a}
CONV	64 ± 11.03 ^{b}	0.29 ± 0.03 ^{a}	0.38 ± 0.13 ^{a}	0.89 ± 0.17 ^{b}	8.44 ± 1.38 ^{b}

Data are presented as means ± standard deviations; n.s.—not significant, **—significant (different letters on the top of data: $^{a, b, c}$ are significantly different at α = 0.05) between means according to Tukey's test. Abbreviations: DP—Dallman porosity, CD—crumb density; RS—resilience; SP—springiness; HD—hardness; ORG—organic; INT—integrated, CONV—conventional.

Crumb density (CD) depended significantly on grain year and genotype (cultivar) (Table 4). Interactions were also found between cultivar and farming system (Figure S4b). The significantly lowest CD was characterised by bread baked from flour from the harvest in 2019 (mean 0.26 g $(cm^3)^{-1}$). The significantly lower CD was characterised by bread baked from flour of the Mandaryna cultivar (mean 0.28 g $(cm^3)^{-1}$) compared to the Harenda cultivar (mean 0.30 g $(cm^3)^{-1}$). A significant effect of cultivar on bread CD was also found by Cacak-Pietrzak et al. [63], while Guerini et al. [64] showed no such relationship. In our study, there was no significant effect of the farming system on CD; the value of this parameter, regardless of agrotechnology intensity, was 0.29 g $(cm^3)^{-1}$. In contrast, the study by Guerini et al. [64] shows significantly higher CD values with increasing agrotechnical intensity.

The CD of wheat bread depends on the baking properties of the flour and the fermentation process of the technological dough. An excessively high CD indicates a compact crumb with low porosity [62]. CD in our study was negatively correlated with BV (r = −0.56,

Figure 1). The CD of the bread samples tested ranged from 0.23–0.34 g $(cm^3)^{-1}$ (Table S4). The lowest CD was characterised by the Mandaryna flour from CONV grain harvested in 2019, and the highest by the Harenda flour from INT and CONV grain harvested in 2020.

Resilience (RS) of bread crumbs depended significantly on grain year and genotype (cultivar) (Table 4). Interactions were also found between cultivar and farming system (Figure S4c). The bread crumbs obtained from flour of grain harvested in 2020 had the highest significantly RS (mean 0.43), while the crumbs from 2021 had the lowest significantly RS (mean 0.30). The crumb with the significantly highest RS was characterised by breads baked from flour of the Harenda cultivar (mean 0.42). The crumb RS of breads made from flour of the other wheat cultivars ranged from 0.33 to 0.35. No significant effect of the farming system on bread crumb RS was found.

Elasticity is a bread crumb parameter that depends on its recipe composition and the technological process [60]. The RS of the bread crumb samples tested was in the range 0.24–0.83 (Table S4). This parameter was positively correlated with DP (r = 0.39, Figure 1). Bread baked from Kandela flour from the ORG harvest in 2019 had the lowest RS value, while bread baked from Harenda flour from the harvest in 2020 from INT had the highest (Table S4).

Springiness (SP) of the bread crumbs depended significantly on the year of grain harvest, genotype (cultivar), and farming system used (Table 4). Interactions were also found between the cultivar and farming system (Figure S4d). The bread crumbs made of flour from grain from the 2021 harvest had the significantly highest SP (mean 0.93). The SP of the bread crumbs made from flour from the cultivars Harenda and Serenada was not significantly different from each other (mean 0.80), while the SP of the crumbs of these breads was significantly lower compared to bread baked from flours from the cultivars Kandela (mean 0.92) and Mandaryna (mean 0.95). The SP of the bread crumbs was also significantly influenced by the farming system used. The bread crumbs made from flour from CONV (mean 0.89), compared to INT (mean 0.85), had the significantly highest SP.

The elasticity of the bread crumbs is a parameter describing the extent to which it returns to its original shape before being compressed [25]. The elasticity of the bread crumb samples tested was in the range 0.29–0.97 (Table S4). The bread crumbs baked from flour of the Serenada cultivar from ORG of 2019 had the least favourable SP, while the bread crumbs made from grain flour of the Mandaryna cultivar from INT of 2020 had the highest SP.

Hardness (HD) of the bread crumbs depended significantly on the year of grain harvest and the farming system used (Table 4). Interactions between the cultivar and the farming system were also shown (Figure S4e). The significantly lowest HD was characterised by the bread crumbs baked from flour obtained from the harvest in 2020 (mean 8.76 N). There was no significant effect of cultivar on the HD of bread crumb; the values of this parameter were similar, and ranged between 7.66 and 7.99 N. In contrast, a study by Rozbicki et al. [11] showed a significant effect of cultivar on bread crumb HD. In our study, a significant effect of farming system on HD of bread crumb was found. The HD of flour samples from grain from ORG and INT was not significantly different (mean 7.44 and 7.47 N, respectively), while it was significantly lower than the HD of bread crumbs from CONV raw materials (mean 8.44 N).

HD is interpreted as the maximum force recorded during the first crushing of the crumb [25]. Our research showed that HD values of bread crumbs depended mainly on CD (r = 0.60) and FN (r = 0.44) (Table 4). Różyło et al. [65] as predictors of HD indicate strength of the dough, FN, and AC. Rozbicki et al. [11], on the other hand, showed a negative correlation between HD and BV. In our study, the significantly lowest HD was characterised by the bread crumbs baked from flour obtained from Harenda cultivar from ORG harvested in 2019 (4.95 N), and the significantly highest by bread baked from flour obtained from INT grain harvested in 2020 (10.54 N) (Table S4).

3.5. Sensory Evaluation of Bread

The most important factors in the consumer's choice of bread are primarily taste and aroma. However, the overall appearance of the loaf, its rise and crust colouring are also important [66]. Sensory parameters of bread, such as appearance (AP), crust colour (CRC), flexibility (FLX), crumb porosity (P), crumb colour (CC), and overall acceptability (OA) were significantly influenced by the year of grain harvest and genotype (cultivar), while none of the parameters studied were influenced by the farming system (Table 5). Considering AP, the highest number of points was awarded to bread baked from flour obtained from grain harvested in 2020 (mean 3.4) and the lowest to bread from 2019 (mean 2.5). According to the panellists, the best AP was characterised by bread made from flour of the Serenada cultivar (mean 3.2), with the differences in the number of points awarded for the appearance of the bread not being statistically significant. According to the panellists, the least favourable CRC was characterised by breads made from flours from grain harvested in 2019 (mean 2.6). The CRC of baked goods from 2020 and 2021 raw materials was rated at a comparable level (means 3.4 and 3.2). In terms of bread crumbs (BC), significantly higher scores were awarded to baked goods made from flour from grain of the Serenada and Kandela cultivars (means 3.6 and 3.4, respectively) than to Mandaryna and Kandela (means 3.0 and 2.9, respectively). In terms of crumb FLX, breads from the wheat cultivars tested were rated similarly (3.0–3.5). Significant differences were only found for the year of harvest, and bread from 2020 and 2021 raw materials were rated higher in terms of this parameter. According to the panellists, bread crumbs from 2020 raw materials was characterised by significantly better P, and considering the genotype, bread made from flour from grain of the Serenada cultivar was rated highest in terms of this parameter (mean 3.1). The number of points awarded for CC was statistically significantly differentiated by year of grain harvest and cultivar. The panellists rated the CC of baked goods from 2019 raw materials least favourably (mean 2.6) than from 2020 and 2022 (means 3.0 and 3.1, respectively). The highest CC score was awarded to baked goods made from grain flour of the Mandaryna cultivar (3.2), and it was significantly higher compared to baked goods made from flour of the Kandela and Harenda cultivars (means 2.6 and 2.8, respectively). According to the panellists, none of the experimental factors significantly affected the T and SM of the breads. The lowest significant number of points for OA was awarded to bread baked from flour obtained from grain harvested in 2019 (mean 2.6, Table 4). It was 13% lower compared to bread made from 2020 and 2021 raw materials. The OA of the bread obtained from ORG wheat grain flour (mean 2.8) was slightly lower than that of the bread from INT and CONV grain flour (mean 2.9). In the sensory evaluation, the highest number of points for OA was awarded to bread made from wheat grain flour of the Serenada cultivar (3.1), which can be associated with the higher content of PC and WG in these raw materials (Table 1), which have a positive effect on bread parameters such as BV and DP. On the other hand, the lowest scores in this respect were given to breads made from flour from grain of the cultivars Mandaryna and Kandela (mean 2.8), which in turn were characterised by a lower PC and WG content (Table 1). The sensory evaluation showed no significant effect of the farming system on OA. It was also not shown in previous study of Cacak-Pietrzak [27]. On the other hand, studies by Sobolewska and Jaroszewska [59] and Krawczyk et al. [67] indicate a higher sensory acceptability of baked goods made from grain flour with CONV than ORG.

3.6. PCA Analysis

Figure 2 shows the result of PCA analysis. First principal component explained 35.26% of the total variance, while the first two components explain over 56% of the variance. The first component was strongly positively related to WG and negatively related to DS, and the second component was strongly positively related to DP and negatively related to SP. The flours from grain from CONV have high positive values of the first and second principal components, so they had high values for features strongly positively correlated with those of principals. Generally, the flours from the grain of cultivars growing in CONV had high value of WG and GI, which indicates their very good baking value. For flours obtained from grain of cultivars growing in ORG and INT, we observed high values of DS and low values for traits such as WG, AC, FN, and WA. The PCA analysis confirms the correlations we observed in Figure 1; in PCA, we observe the same relationships between variables that were observed in the correlation analysis.

Table 5. Sensory evaluation of bread depending on the harvest year, cultivar, and farming system.

Source of Variation	AP	CRC	BC	FLX	P	CC	T	SM	OA
Year	**	**	n.s.	**	**	**	n.s.	n.s.	**
2019	2.5 ± 1.23 [a]	2.6 ± 1.14 [a]	3.3 ± 0.88 [a]	2.9 ± 1.19 [a]	2.4 ± 1.69 [a]	2.6 ± 1.02 [a]	2.4 ± 1.21 [a]	2.6 ± 1.18 [a]	2.6 ± 0.64 [a]
2020	3.4 ± 1.16 [b]	3.4 ± 1.01 [b]	3.2 ± 0.76 [a]	3.3 ± 1.06 [b]	3.1 ± 1.28 [b]	3.1 ± 1.42 [b]	2.5 ± 1.69 [a]	2.2 ± 1.23 [a]	3.0 ± 0.80 [b]
2021	2.9 ± 1.22 [ab]	3.2 ± 1.46 [b]	3.2 ± 1.28 [a]	3.3 ± 1.51 [b]	2.3 ± 1.18 [a]	3.0 ± 1.44 [b]	2.6 ± 1.55 [a]	2.4 ± 1.4 [a]	2.9 ± 0.97 [b]
Cultivar	n.s.	n.s.	**	n.s.	**	**	n.s.	n.s.	n.s.
Harenda	2.7 ± 1.10 [a]	3.0 ± 1.48 [a]	2.9 ± 0.78 [a]	3.0 ± 1.15 [a]	2.3 ± 1.66 [a]	2.8 ± 1.38 [a]	2.4 ± 1.55 [a]	2.1 ± 1.27 [a]	2.7 ± 0.86 [a]
Mandaryna	2.9 ± 1.55 [a]	3.0 ± 1.54 [a]	3.0 ± 0.82 [a]	3.1 ± 1.02 [a]	2.4 ± 1.45 [a]	3.2 ± 1.74 [b]	2.5 ± 1.45 [a]	2.5 ± 1.17 [a]	2.8 ± 0.89 [a]
Kandela	2.8 ± 1.09 [a]	2.9 ± 0.75 [a]	3.4 ± 0.80 [b]	3.0 ± 1.40 [a]	2.6 ± 1.33 [a]	2.6 ± 1.01 [a]	2.5 ± 1.34 [a]	2.4 ± 1.15 [a]	2.8 ± 0.61 [a]
Serenada	3.2 ± 1.01 [a]	3.4 ± 0.85 [a]	3.6 ± 1.43 [b]	3.5 ± 1.47 [a]	3.1 ± 1.05 [b]	3.0 ± 1.00 [ab]	2.6 ± 1.62 [a]	2.6 ± 1.49 [a]	3.1 ± 0.87 [a]
Farming system	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
ORG	2.9 ± 1.08 [a]	3.0 ± 1.13 [a]	3.2 ± 1.36 [a]	3.1 ± 1.3 [a]	2.6 ± 1.11 [a]	3.0 ± 1.05 [a]	2.5 ± 1.36 [a]	2.5 ± 1.34 [a]	2.8 ± 0.86 [a]
INT	3.0 ± 1.48 [a]	3.2 ± 1.48 [a]	3.2 ± 0.81 [a]	3.3 ± 1.05 [a]	2.6 ± 1.54 [a]	2.9 ± 1.68 [a]	2.4 ± 1.69 [a]	2.4 ± 1.35 [a]	2.9 ± 0.86 [a]
CONV	3.0 ± 0.85 [a]	3.1 ± 1.06 [a]	3.3 ± 0.68 [a]	3.2 ± 1.39 [a]	2.6 ± 1.43 [a]	2.9 ± 1.06 [a]	2.6 ± 1.38 [a]	2.4 ± 1.06 [a]	2.9 ± 0.67 [a]

Data are presented as means ± standard deviations; n.s.—not significant, **—significant (different letters on the top of data: [a, b] are significantly different at α = 0.05). Abbreviations: AP—appearance; CRC—crust colour; BC—bread crust; FLX—flexibility; P—porosity; CC—crumb colour; T—taste; SM—smell; OA—overall acceptability; ORG—organic; INT—integrated, CONV—conventional.

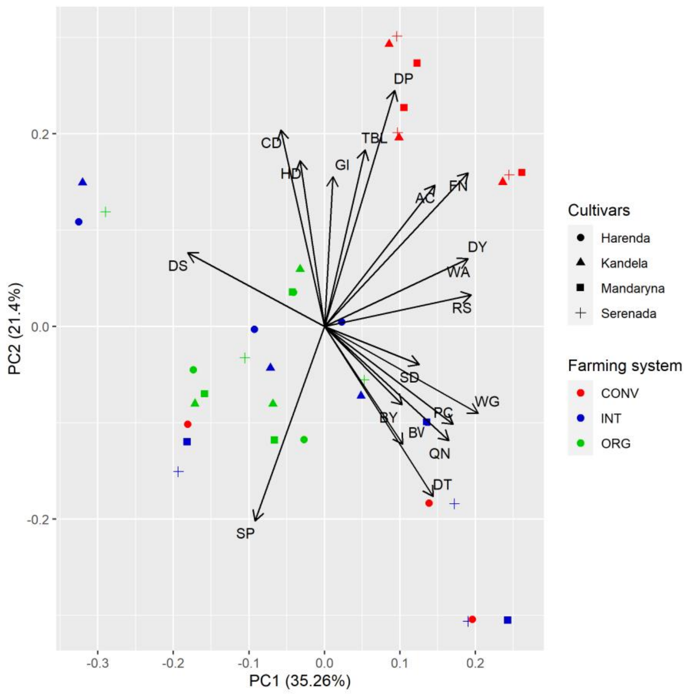

Figure 2. PCA analysis for study traits. Abbreviations: AC—ash content; PC—protein content, WG—wet gluten; GI—gluten index, FN—falling number, WA—water absorption; DT—development time; SD—stability; DS—degree of softening; QN—quality number; TBL—total baking loss; DY—dough yield; BY—bread yield; BV—bread volume; DP—Dallman porosity; CD—crumb density; RS—resilience; SP—springiness; HD—hardness; ORG—organic; INT—integrated; CONV—conventional.

4. Conclusions

Our research is in line with current trends in the European Union promoting sustainable development and striving to reduce the use of mineral fertilizers and chemical plant protection products in agriculture. Growing wheat in CONV had a slightly more positive effect on the quality parameters of flour and rheological properties of dough than cultivation in less intensive farming systems, especially ORG. Nevertheless, we have shown that by cultivating wheat in a less intensive way (ORG, INT), it is possible to obtain a raw material that meets the requirements of the baking industry, including in relation to such an important parameter as WG. Flours from INT grains were characterized by the significantly highest WA, which resulted in higher DY and BY, and bread made from these flours had a significantly highest BV. The baking value of flour was also influenced by the cultivar and meteorological conditions in growing season. In our work, in relation to most of the parameters examined, there was a diversified response of cultivars to the farming system used in cultivation. The best technological quality, regardless of the production system, was characterized by flour from the Serenada cultivar, which was also indicated as the cultivar recommended for cultivation in INT and ORG. The results obtained prove how important it is to select the appropriate cultivar for a specific farming system. Moreover, the sensory evaluation showed that bread made from ORG wheat flour was characterized by only slightly lower quality than bread made from wheat flour from the grain from other two farming systems.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app14051886/s1, Figure S1: The interaction effects of cultivar and farming system on the quality parameters of wheat flour; Figure S2: The interaction effects of cultivar and farming system on water absorption of wheat flour and rheological properties of dough; Figure S3: The interaction effects of cultivar and farming system on baking process parameters and quality indicators of wheat bread; Figure S4: The interaction effects of cultivar and farming system on the quality indicators of bread crumbs; Table S1: Quality parameters of flour; Table S2: The water absorption of flour and rheological properties of wheat dough; Table S3: Baking process parameters and quality indicators of bread; Table S4: The quality indicators of bread crumbs.

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