ROLE OF POST-HARVEST RESIDUE TREATMENT ON THE WHEAT PRODUCTIVITY, FLOUR PROPERTIES AND BREAD-MAKING QUALITIES

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ABSTRACT

The effect of the soil tillage and sowing machines (Tradicional system - TS and Combination - CS) and of the type of the previous crop post-harvest residue treatment (common bean, maize, sunflower) on the wheat flour properties and bread-making qualities were investigated in six-field crop rotation. The wheat post-harvest residues (PHR) were utilized in three different ways (removed from the field -RF; chopped and subsequently incorporated into the soil - I; and burned - B). The trail was carried out at Dobrudzha Agricultural Institute on Haplic Chernozems.

It is characteristic for the research period that the bean predecessor in both systems increases the farinographic evaluations of stretchability and stability of the dough, degree of softening and the number of the quality coefficient of the flour. Except for the softening degree data, the TS has contributed higher data values for the listed indicators compared to the CS one. Sedimentation and wet/dry gluten content highest after maize predecessor and again with TS.

The removal of plant residues from the field leads to an increase in the values of sedimentation (TS-CS), wet gluten (TS), dough stability (TS-CS) and especially the rheological properties. Contrary, incorporation of plant residue into the soil leads to a noticeable decrease in the values of these indicators. However, in the case of CS, the same leads to an increase in the values of the degree of softening. It was also found that the burning of post-harvest residues and CS leads to higher values of wet gluten and increases the extensibility of the dough.

The years with an optimal combination of the main meteorological elements (2017) have a significant contribution to obtain higher values for sedimentation, wet/dry gluten and farinographic indices for quality. In years with an insufficient amount of precipitation combined with higher temperatures in critical phases of the permanent wheat vegetation (2018), the dough extensibility and degrees of softening are higher compared to the other years.

Bread volume is the quality characteristic that is practically unaffected by the way of using the post-harvest residues and by its interactions with other factors in both tested systems. Its values in both systems are mainly influenced by the meteorological factor, and this fact is to a much greater extent valid for TS compared to CS. Multiple correlations were established between the tested qualitative characteristics of the tested indicators by years of research and average for the period. They differ both in the direction of interaction and in the strength of the correlation dependences by sowing systems.

KEY WORDS: Ways of utilization of post harvest residue, wheat, lour properties, bread-making qualities

INTRODUCTION

The qualitative characteristics of the wheat grain are a complex of chemical composition of the grain, biochemical, technological and bakery properties. They are highly dependent both on the genetics of the variety and, in general, on the growing conditions. The latter, in turn, include the system of agriculture, the characteristics of the soil type and care for its fertility, the type and method of introducing nutrients, the soil tillage systems in the crop rotation.

The current stage of agricultural production in the world requires expanding knowledge about the impact of plant residues from the previous crop on soil properties and the development, productivity and quality of the next crop in the crop rotation. The processes of desertification, reduction of the area of agricultural lands worldwide and a number of crises accompanying the modern human world further strengthen the need to expand our knowledge of post-harvest residues so that they can be maximally effective. Their amount as total biomass, nutrient content, C/N ratio and others depend on the type of crop and its cultivation technology (Singh et al. 2005, Shi 2013, Torma et al., 2018). According to Matumba et al. (2021) cereal crops are considered highly susceptible to various types of infections during the pre- and post-harvest stages. A number of studies show that there is undoubtedly a connection with what plant residues contain, including the possibility of provoking the development of diseases, multiplication of enemies, decomposition time and others (Medina et al., Abou Dib et al., 2022; 2017, Gómez et al., 2022).

We are witnessing real climate change that seems inevitable. This fact threatens terrestrial ecosystems and the production of agricultural products. According to Maity et al. (2023) climatic anomalies, may not always seriously affect the yield, but may reduce the morphological, physiological and biochemical quality of the produce. A special imprint on the biological value of the quality indicators is left by the climatic conditions, which together with the overall agrotechnics put every variety to a serious test (Nankova et al, 2020).

The aim of the research is to evaluate the changes in a number of quality indices characterizing the bread-making properties of the Enola variety, depending on the type of plant residues of the predecessors and the ways of their use.

MATERIAL AND METHODS

The research was conducted during the period 2017-2019 in a long-term stationary field experiment in the Experimental Field of at Dobrudzha Agricultural Institute on Haplic Chernozems. The same is the 6-field six-field crop rotation (grain maize–wheat–sunflower–wheat–bean–wheat). Plant post-harvest residues (PHR) from the 3 predecessors of wheat (beans-sunflower-corn) are utilized in three different ways: they were removed from the field (RF); they were burned (B) and they were chopped and subsequently incorporated into soil (CSIS).

The trial was performed on 10 ha area in 4 replicates. The mineral fertilization of the spring crops in the crop rotation were applied as follows: bean – $N_{60}P_{100}K_0$; sunflower – $N_{60}P_{100}K_0$; and maize – $N_{120}P_{100}K_0$. Two systems of machines - traditional and combined - were used for tillage and sowing. Soil preparation in the traditional system (TS) includes 2-fold discing and sowing with SZU-3,6. The combined system is the aggregation of a Fendt 820 Vario tractor and a Horsch 6.0 planter with a preliminary single discing, and the second is together with sowing. In both systems, sowing was carried out at a rate of 500 g.s/m^2.

During the study, the changes in the values of the following indicators, characterizing the bakery properties of the Enola variety, were investigated: sedimentation value of flour, ml (SED) (Pumpyanskii, 1971); wet gluten content in grain, % (WGC) (BSS 13375-88); dough development, min (DD); stability of the dough, min (SD); degree of softening, f.u. (DS); number of the quality coefficient of the flour (NQCF); bread loaf volume, ml (LVol).The preparation of the samples and their grinding was carried out on a mill MLU-202 up to 70% flour.

The results were processed statistically using analysis of variance (Anova), while the significance of differences between mean values was evaluated with the Waller-Duncan's HSD test, $P < 0.05$. The value of variability for traits was determined and expressed by coefficient of variation of traits. Pearson correlation coefficients ("R coefficients") were computed and tested for significance.

RESULTS AND DISCUTIONS

At the Dobrudja Agricultural Institute, research on the use of plant residues dates back to the beginning of the 21st century and covers the ways of using different types of plant post-harvest residues (PHR) on the productivity and quality of the crops included in the crop rotation (Nankova et al., 2010; Iliev et al., 2018; Iliev, 2021), as well as the use of various products to accelerate their decomposition (Milev et al., 2014). Some of the obtained results have been published in various international forums and scientific journals. The present publication is the first to treat the influence of plant residues from different predecessors and their utilization methods on the baking qualities of the Enola variety.

The reaction of this wheat cultivar to the tested factors in the experiment was highly expressed both by year and depending on the tested sowing systems (Table 1). In 2017, all quality indeces have higher values for TS of sowing compared to CS with a pronounced variation between min and max values. The LVol and SED indeces are characterized by the lowest variation, and the difference between the systems is insignificant. The yield of wet gluten (WGC) in the grain is characterized by an increase in CV% values, but they are still below 30%. The number for the quality coefficient of flour (NQCF) shows the largest difference in CV% values - 11.90 % for TS and 54.52% for CS. The latter is an indication of high scatter in the data and, accordingly, non-uniformity of the sample. The variation in the data characterizing the rheological properties of the dough depending on the used system of seeding machines is also characterized by a strong dynamic in the indicated statistical parameters.

Table 1. Degree of variation in the performance of the quality parameters according to sowing systems by years of investigation

Stat. Parameters	SED, ml		WGC, %		DD, min		SD, min		DS, f.u.		NQCF		LVol	
	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS
2017														
Minimum	34.00	29.00	16.30	13.10	2.00	1.90	2.00	1.80	33.00	33.00	74.00	0.00	555.00	550.00
Maximum	54.50	51.50	28.90	27.60	5.55	4.85	8.30	8.30	110.00	111.00	110.00	114.00	665.00	645.00
Mean	**44.04**	**40.22**	**23.28**	**20.42**	**3.37**	**3.08**	**5.50**	**4.83**	**80.47**	**71.39**	**89.72**	**72.22**	**615.00**	**604.17**
Std. Deviation	7.58	6.95	4.37	5.30	1.30	1.22	2.00	2.10	26.89	26.70	10.68	39.38	28.18	29.42
CV%	*17.21*	*17.29*	*18.75*	*25.96*	*38.59*	*39.72*	*36.34*	*43.42*	*33.42*	*37.41*	*11.90*	*54.52*	*4.58*	*4.87*
2018														
Minimum	8.00	6.00	0.00	2.10	2.95	3.00	2.10	2.20	41.00	46.00	203.00	192.00	500.00	500.00
Maximum	53.00	56.00	22.80	26.30	4.25	4.45	3.15	3.60	58.00	62.50	253.00	275.00	605.00	650.00
Mean	**32.89**	**36.17**	**12.29**	**14.82**	**3.40**	**3.79**	**2.62**	**2.80**	**49.65**	**51.51**	**229.11**	**225.72**	**557.22**	**564.72**
Std. Deviation	19.12	19.64	8.56	7.86	0.38	0.44	0.30	0.36	4.67	5.24	15.04	21.26	25.22	38.10
CV%	*58.13*	*54.31*	*69.68*	*53.02*	*11.22*	*11.68*	*11.38*	*12.89*	*9.41*	*10.18*	*6.57*	*9.42*	*4.53*	*6.75*
2019														
Minimum	32.00	32.00	4.30	4.10	1.70	1.70	1.80	2.00	29.00	28.00	59.00	55.00	575.00	535.00
Maximum	46.00	42.00	22.65	21.05	6.30	6.30	9.55	8.05	121.00	102.00	118.00	121.00	679.00	660.00
Mean	**39.28**	**36.94**	**14.77**	**12.00**	**2.48**	**2.41**	**5.94**	**5.10**	**75.22**	**67.17**	**86.56**	**88.50**	**628.00**	**601.94**
Std. Deviation	5.14	2.86	5.58	5.12	1.40	1.42	3.15	2.39	35.50	29.34	16.61	17.91	31.02	34.60
CV%	*13.09*	*7.74*	*37.81*	*42.70*	*56.70*	*58.66*	*53.09*	*46.78*	*47.20*	*43.68*	*19.19*	*20.24*	*4.94*	*5.75*

During the next two years of the study, we observed a highly changed reaction of the variety depending on the weather conditions. Its detailed characterization is presented in Nankova and Iliev (2023). The strong drought in critical phases of the spring vegetation in 2018 leads to the lower average values for SED, but with a much more pronounced variation between the maximum and minimum values of the indicator and in the 2 systems. Year conditions also contributed to lower absolute values of dough stability (SD) and degree of softening (DS) during the study. At the same time, the average values of the number for the flour quality factor (NQCF) marked its highest absolute values and lowest CV%.

Dough development time (DD) was characterized by relatively close values, regardless of the seeding machine systems used during the years of research. However, this fact is accompanied by a very large dynamic of variation, which is why the sample in 2019 is the most heterogeneous. Of all the indeces studied over the years, the volume of the bread is the quality characteristic that is subject to the lowest dynamics in this experimental setup. CV% values ranged from 4.58% to 6.75% during the study period.

During the years of research, the sedimentation of Enola variety flour is significantly influenced by the type of plant residues of the previous crop and the ways of their utilization (Figure 1). In the year with the most favorable combination of the main meteorological elements (2017), the bean predecessor increased the SED values and, regardless of the cropping systems, maize proved to be a better predecessor than sunflower. Definitely with higher SED^s is the flour when using TS. The values for the rheological properties of the dough are subject to significant differentiation depending on the type of plant residues of the previous crop and the methods of their utilization in the agricultural technique used. In severe drought during the perennial vegetation (2018) it is distinguished by the highest fluctuation in the obtained SED results depending on the type of predecessor. It was found that regardless of the machinery system, after the maize predecessor, the flour had the highest SED and the bean the lowest. In 2019 (with rainfall below the climatic norm, but relatively evenly distributed), again the predecessors beans and corn are better compared to sunflower. The influence of the cropping systems used on the mean SED values was most pronounced after the predecessor bean and when TS was used. A stronger positive influence of CS was found after sunflower PHR.

The WGC index reached a maximum value (26.45%) for the entire study period in 2017, with the bean predecessor and TS leading to better results. Under conditions of severe moisture deficit (2018), the use of CS contributes to obtaining higher values (14.82%) compared to TS (12.99%). After the bean predecessor, the influence of the systems on the WGC values was practically equalized, while after maize and sunflower, the application of CS definitely gave better results compared to the traditional way of sowing. In 2019, better average scores were again obtained for the indicator after the implementation of TS (14.77%) compared to CS (12.00%).

During the first two years of the study, growing wheat under TS resulted in an increase in dough development time (DD) compared to CS. Under the conditions of a moderate moisture deficit, but relatively uniform distribution of precipitation, an approximately equal response was found in the values of this indicator for the tested sowing machine systems. Dough development (DD) took relatively longer after predecessor beans in 2017 and 2019. Conversely, severe drought conditions during grain formation lead to a reduction in DD when growing wheat after beans and an increase after sunflower and corn. In general, in 2019 the dough formation time was shorter compared to the other years of the study.

Dough stability (SD) values show that application of TS in 2017 and 2019 contributes to obtaining dough with higher stability (SD) compared to CS (5.50-4.83). In 2018, the contribution of CS to obtaining a more stable dough is greater compared to that of TS. Using the CS with all three predecessors consistently gives better results. Predecessor maize (2018) has the greatest contribution to obtain dough with high stability. 2019 is the year in which the dough has the highest stability. The greatest contribution to this is made by the plant residues of beans, followed by those of maize and sunflower, whose values are close. In the sunflower PHR, the difference in influence of the systems is unnoticeable, while in the maize PHR it is drastically in favor of TS.

The values for the degree of softening of the dough (DS f.u.) show a strong differentiation depending on the type of plant residues of the predecessor. Similar to dough stability (SD) in 2019, values obtained for the indicator were higher for TS compared to CS. For 2018, the trend for the strong influence of CS on the values of the indicator compared to the cultivation of wheat under TS has been preserved. Utilization of sunflower residues in 2017 contributed to increase the values for the degree of softening of the dough when applying CS compared to TS. In 2018 on its impact on DS f.u. predecessors are arranged in the following order: corn>sunflower>bean. Characteristically, in 2019, the application of CS after a sunflower PHR leads to obtaining higher values of the indicator compared to TS. In the case of predecessor maize, a sharp drop in the values of the indicator was found at CS (40.33) compared to TS (71.33).

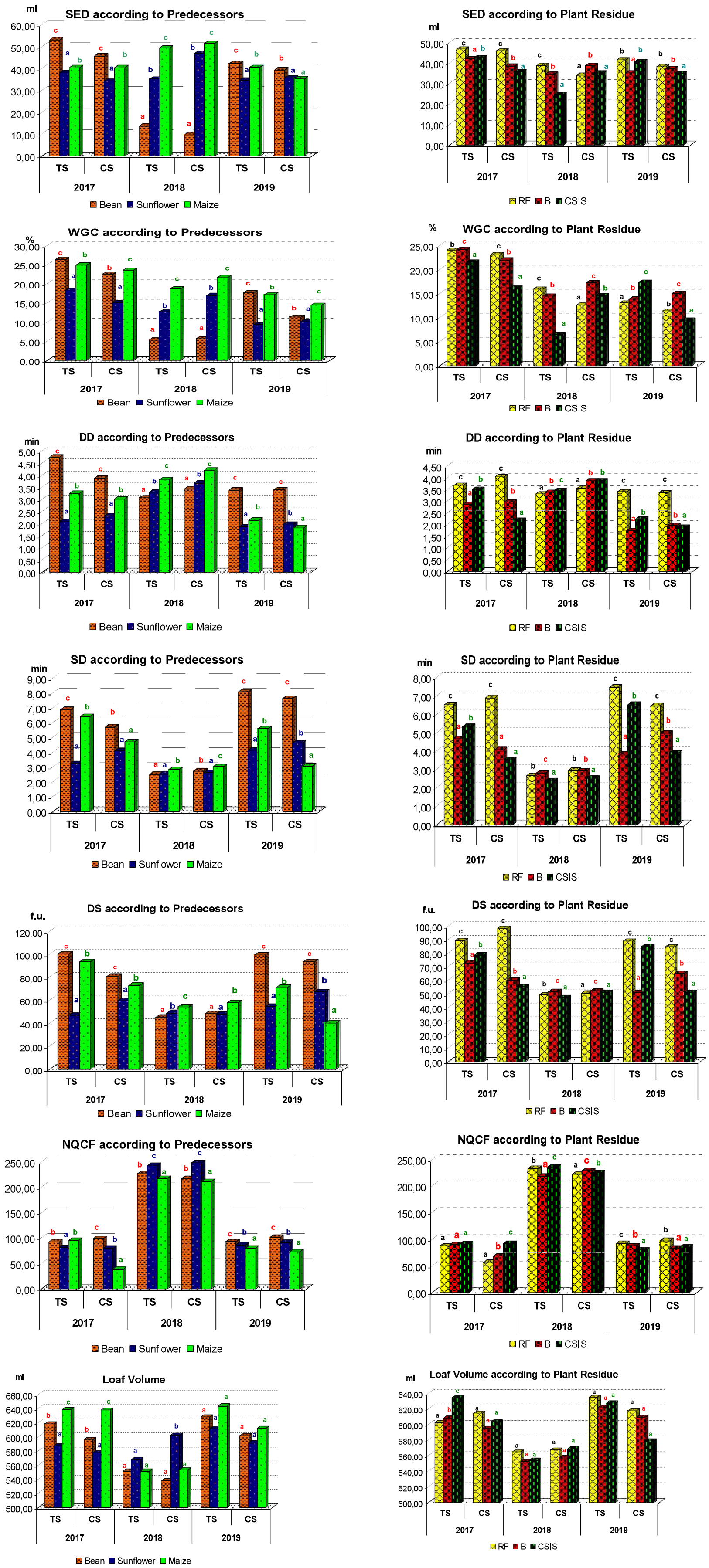


Figure 1. Dynamics in quality characteristics of flour and dough by years of research depending on the factors in the experiment

The differentiation in the values of the quality coefficient of the flour (NGCF) according to the type of plant residues of the predecessor varied according to the tested sowing machine systems and according to the weather conditions during the years of the study. In 2017, no strong differentiation was found depending on the type of plant remains of the predecessor in TS, while in CS the same was maximally manifested. In traditional sowing, bean and maize predecessors have approximately equal impact on NGCF, and after sunflower PHR the values of the indicator are the lowest. In the use of CS, the influence of predecessors was in the following order: bean>sunflower>maize. Regardless of this fact, the values of the indicator when using TS (89.72) are higher compared to those obtained with CS (72.22). This is the year with the lowest values of the index. The NGCF has the highest values for the experiment period in 2018. Differentiation between predecessors is reliable, with both systems having the highest values after sunflower, followed by beans and maize PHR. In 2019 NGCF has lower values compared to 2018. The differentiation between predecessors is also credible. In terms of influence, the contribution of predecessors PHR is in the following order: beans>sunflower>maize.

Statistically significant differentiation for the influence of plant residues from the predecessor on the volume of bread (LVol) was found only in 2017 when using TS. The impact of the tested PHR was practically equalized. In 2018 and 2019, the differences in LVol values were statistically implausible. The year with the lowest values for the volume of bread is 2018, and in 2019 - bread has the largest volume.

What will be our attitude to the plant residues of the predecessor and our agrotechnical solutions for their utilization over the years also have a significant impact on the quality characteristics of the grain, flour and the rheological properties of the dough.

The sedimentation value of flour (SED) is significantly influenced by weather conditions and methods of utilization of plant residues from the previous crop. In years with favorable conditions field RF and TS seeding are preferred. In the conditions of strong water deficit (2018), the burning of plant residues and the use of CS leads to the obtaining of higher SEDs compared to the other two ways of their utilization. Returning the entire amount of plant mass from the predecessor in suitable condition (CSIS) is only recommended when using TS for soil preparation and seeding. Under conditions of uniform water deficit during the growing season (2019), flour sedimentation has higher values at TS. In this sowing method, the best results were obtained in the following order RF>CSIS>B, while CS sowing method ranked the ways of using the post-harvest residues as follows: RF>B>CSIS.

Favorable weather conditions (2017) lead to obtaining more WGC for the study period and a significant contribution of the use of TS compared to CS. RF and B of PHR have relatively equal influence on gluten, while when they are plowed, especially CS there is a sharp drop in the values of the indicator - by more than 5 points compared to B and by more than 7 points - in RF. CS sowing has a significant advantage over TS in terms of WGC values under drought conditions. When applying TS, a sharp drop in the values of the obtained results was observed in the direction from RF to CSIS, while with CS, the highest values for gluten were obtained in the variants with B and the lowest - at RF. The positive influence of TS compared to CS on WGC values was again established in 2019, with both systems being the highest after B.

Dough formation time (DD) in RF and using CS exceeded the same in TS. In both sowing systems, B results in approximately the same values, while in CSIS the formation of the dough in TS is longer compared to CS. In the conditions of critical droughts (2018), regardless of the method of RO utilization, the use of CS leads to an extension of the dough formation time compared to TS. Within each of the systems, the differences between individual ways of treating PO are narrowed. RF in both systems speeds up dough development time. In 2019, the formation of the dough in both systems takes approximately the same time. The same is shortest in the PHR burn variant, followed by CSIS. The variant with RF is characterized by the longest time for forming the dough.

Higher dough resistance (SD) in 2017 was found in the RF variant, and for this fact the contribution of CS is significant. The stability of the dough is reduced when burning the PHR, and the difference between the two systems is too small. Severe water deficit (2018) lowers dough stability and reduces variation in PHR usage patterns. On the contrary, with a uniform water deficit during the growing season (2019), a strong differentiation is observed depending on the ways of using the predecessor PHR. In both systems, RF has the most significant contribution to increasing dough stability. For TS, CSIS also scores highly for this index, but CS is highly inadvisable for PHR incorporation.

For the degree of softening of the dough (DS f.u.) it is characteristic that under the conditions of moisture deficiency (2018 and 2019) the variants with B and use of CS obtained higher values for this indicator compared to TS. It was found that CSIS, especially those from maize, in 2019 resulted in a sharp decrease in the degree of softening of the dough. DS f.u. in 2017 it had the highest values at RF of PHR, and at CS of sowing the values were higher than those obtained at TS of sowing.

Higher flour quality coefficient (NGCF) was found in CSIS of PHR, followed by RF and lowest - in B. This trend was observed in 2018 in CS at sowing and in 2019 - TS. No differentiation was found depending on the method of utilization of plant residues in TS of sowing in 2017, while in CS the same was clearly manifested. The highest flour quality coefficient was found for CSIS and the lowest for the RF variant of PHR.

Within the experiment, there is a differentiation in the values for the volume of the bread only by years of study. On average, for this time period, neither the type of plant residues from the previous crop, nor the methods of their utilization reliably influence the volume of bread for the period 2017-2019.

Based on the statistical analysis, the reliability of the above-mentioned differences between the tested factors in the experiment and their influence on the quality characteristics of the grain, flour and the rheological properties of the dough has been established (Table 2). On average for the studied period, only LVol is not statistically reliably affected by the independent effect of the type of plant residues of the previous crop and the way of their use. Of all the types of interactions, the same indeces is reliably affected only by the combined interaction *Year x Predecessor*.

The average values of the tested quality characteristics for the period 2017-2019 for the approach to each machine system show the strong influence of the conditions of the year (Table 3). For both tested seeding machine systems, the highest values for SED, ml and WGC,% indicators were obtained in 2017 when seeding was carried out in a traditional way. In terms of average data for dough development time, its stability and quality factor number, the values were the lowest in 2018. The same applies to the LVol, but the statistical analysis of the data shows that the differences found are unreliable. The year with extreme droughts in critical phases during the growing season and both systems are characterized by the highest values for the degree of softening of the dough.

The role of PHR of the predecessor is clearly expressed. With the traditional method of sowing, with the exception of the degree of softening of the dough (DS f.u.), all quality characteristics have the lowest values in the predecessor sunflower (Table 4). This trend is less pronounced for CS and does not affect indicators such as SED, WGC, DS f.u. and NGCF. The most significant difference in the influence of the two systems was found in the indeces WGC and SED, where in the variants with the bean's PHR the superiority of TS compared to CS was more pronounced. For the specified quality characteristics, this increase is respectively 25.10% and 15.14%. Traditional sowing after PHR of corn greatly increased the values of the rheological properties SD, DS f.u. and NQCF. This increase compared to CS is respectively 37.10%, 27.98% and 21.76%.

Comparing the two systems of sowing after PHR of sunflower, the obtained results show that, despite the lower values after this predecessor, CS has a more pronounced positive influence on quality compared to TS. This fact is most pronounced in the indeces SD (min) and DS f.u., whose values in TS are respectively 87.14% and 86.21% of those obtained in CS. It was also found that the quality results obtained after the sunflower predecessor were below the average of the three predecessors and this fact was most pronounced for the DS f.u. and WGC.

Table 2. Analysis of variances of bread making qualities according to the ways of PHR utilization over years and averaged for the period 2017 – 2019.

Source 2017-2019	Dependent Variable	df	TS Mean Square	TS F	TS Sig	CS Mean Square	CS F	CS Sig
Years (1)	SED	2	563.43	684.17	.000	83.39	82.41	.000
	WGC	2	598.34	249502.00	.000	330.73	86277.28	.000
	DD	2	4.96	4116.81	.000	8.51	7070.191	.000
	SD	2	58.51	30822.15	.000	28.56	181.09	.000
	DS f.u.	2	119284.13	21399.81	.000	127971.46	19744.17	.000
	NQCF	2	4893.59	5618.54	.000	1975.33	2343.84	.000
	LVol	2	25550.30	56.05	.000	8838.89	13.03	.000
Predecessor (2)	SED	2	318.25	386.45	.000	549.76	543.32	.000
	WGC	2	211.90	88361.33	.000	240.57	62756.40	.000
	DD	2	7.80	6481.39	.000	3.81	3168.12	.000
	SD	2	29.51	15546.15	.000	16.74	106.14	.000
	DS f.u.	2	245.13	43.98	.000	6134.46	946.46	.000
	NQCF	2	4769.52	5476.08	.000	1685.63	2000.09	.000
	LVol	2	2272.24	4.99	$.014^{NS}$	2279.17	3.36	$.050^{NS}$
PlantRezidue (3)	SED	2	205.85	249.97	.000	82.34	81.37	.000
	WGC	2	35.70	14888.18	.000	99.33	25911.58	.000
	DD	2	2.94	2442.81	.000	4.85	4026.12	.000
	SD	2	14.27	7519.24	.000	21.17	134.22	.000
	DS f.u.	2	151.24	27.13	.000	428.13	66.05	.000
	NQCF	2	1403.68	1611.63	.000	3085.50	3661.10	.000
	LVol	2	562.24	1.23	$.307^{NS}$	1254.17	1.85	$.177^{NS}$
1 x 2	SED	4	1055.13	1281.25	.000	1417.93	1401.32	.000
	WGC	4	150.93	62937.28	.000	162.61	42419.39	.000
	DD	4	3.87	3214.39	.000	2.66	2205.46	.000
	SD	4	9.18	4833.73	.000	9.91	62.82	.000
	DS f.u.	4	650.35	116.67	.000	1610.82	248.53	.000
	NQCF	4	1755.97	2016.10	.000	1747.48	2073.47	.000
	LVol	4	1953.07	4.28	.008	5468.06	8.06	.000
1 x 3	SED	4	112.43	136.53	.000	73.06	72.20	.000
	WGC	4	82.21	34279.55	.000	32.47	8469.50	.000
	DD	4	1.32	1099.39	.000	2.35	1952.14	.000
	SD	4	6.24	3287.82	.000	4.36	27.66	.000
	DS f.u.	4	324.96	58.30	.000	993.16	153.23	.000
	NQCF	4	814.64	935.32	.000	979.63	1162.38	.000
	LVol	4	839.74	1.84	$.150^{NS}$	988.89	1.46	$.242^{NS}$
2 x 3	SED	4	264.18	320.80	.000	12.41	12.27	.000
	WGC	4	33.41	13929.49	.000	49.34	12871.65	.000
	DD	4	.70	579.64	.000	1.56	1298.54	.000
	SD	4	8.32	4382.93	.000	4.14	26.24	.000
	DS f.u.	4	503.13	90.26	.000	2210.82	341.10	.000
	NQCF	4	1163.14	1335.45	.000	906.04	1075.07	.000
	LVol	4	1687.52	3.70	$.016^{NS}$	1312.50	1.94	$.133^{NS}$
1 x 2 x 3	SED	8	105.28	127.84	.000	26.76	26.45	.000
	WGC	8	67.42	28112.95	.000	39.49	10302.48	.000
	DD	8	2.46	2044.90	.000	2.41	1999.07	.000
	SD	8	6.97	3671,10	.000	2.52	16.00	.000
	DS f.u.	8	452.35	81,15	.000	866.98	133.76	.000
	NQCF	8	848.97	974,74	.000	390.78	463.69	.000
	LVol	8	595.85	1,31	$.282^{NS}$	410.76	.61	$.765^{NS}$

The ways of using the plant residues also have a significant dynamic in the values of the investigated quality characteristics (Table 5). The sedimentation value of flour averaged over the period has the highest values in RF and TS sowing. The excess compared to CS is 7.58%. The burning and incorporation of plant mass leads to a gradual decrease in the values of this index. The average excess when using TS compared to CS is 2.53%.

Table 3. Mean data of the values of the end use quality depending on the years of investigation (2017-2019)

Years	SED, ml	WGC, %	DD, min	SD, min	DS, f.u.	NGCF	LVol, ml
TS							
2017	44.04 c	23.28 c	3.37 b	5.50 b	89.72 b	80.47 c	615.00 b
2018	32.89 a	12.29 a	3.40 c	2.62 a	229.11 c	49.65 a	557.22 a
2019	39.28 b	14.77 b	2.48 a	5.94 c	86.56 a	75.22 b	628.00 b
CS							
2017	40.22 c	20.42 c	3.08 b	4.83 b	72.22 a	71.39 c	604.17 b
2018	36.17 a	14.82 b	3.79 c	2.80 a	225.72 c	51.51 a	564.72 a
2019	36.94 b	12.00 a	2.41 a	5.10 c	88.50 b	67.17 b	601.94 b

Table 4. Mean data of the values of the bread-making quality depending on the kind of the previous crop PHR (2017-2019)

PHR Predecessors	SED, ml	WGC,%	DD, min	SD, min	DS, f.u.	NGCF	LVol, ml
TS							
Bean	36.54 a	16.53 b	3.74 c	5.82 c	137.61 b	81.85 c	599.44 ab
Sunflower	36.08 a	13.48 a	2.43 a	3.30 a	136.89 b	50.33 a	589.17 a
Maize	43.58 b	20.33 c	3.08 b	4.94 b	130.89 a	73.17 b	611.61 b
CS							
Bean	31.73 a	13.21 a	3.58 c	5.35 b	139.22 b	74.51 c	578.89 a
Sunflower	39.03 b	14.09 b	2.67 a	3.78 a	139.72 b	58.39 b	590.56 ab
Maize	42.57 c	19.94 c	3.03 b	3.60 a	107.50 a	57.17 a	601.39 b

In both systems, the CSIS had the most unfavorable effect on the WGC values. In TS, there is practically no difference between the RF and B variants, but in CS, residue burning results in the highest average values in the experiment (18.11%). Regarding the values of this index, TS leads to an average excess compared to CS by 6.57%

The rheological properties of the dough are also, although to a different extent, influenced by the use methods of the plant residues of the predecessor. Regardless of this fact, no significant differences were found in DD on average for the 2 sowing systems. In the variants with RF and B, the extensibility of the dough has higher values in CS compared to TS, while in CSIS a significant excess of TS compared to SC was found - on average by 16.04%. It was also found that the inclusion of the entire amount of plant residues leads to an increase in the stability of the dough (SD) in the TS by 43.36% compared to the values obtained in the combined one. The average excess of TS compared to CS by 10.42%. A similar trend was also found for the indicator DS f.u. in the variant with incorporation (CSIS) and use of TS, where the excess compared to CS is 33.83%. With this index, the average increase in values is respectively 8.04% compared to CS.

Table 5. Mean data of the values of the bread-making quality depending on the way of utilization of the previous crop PHR (2017-2019)

Plant Residue	SED, ml	WGC, %	DD, min	SD, min	DS, f.u.	NGCF	LVol, ml
TS							
RF	42.57 c	17.66 c	3.49 c	5.54 c	137.72 c	76.04 c	600.78 a
B	37.44 b	17.53 b	2.68 a	3.77 a	132.00 a	58.76 a	594.17 a
CSIS	36.19 a	15.16 a	3.09 b	4.75 b	135.67 b	70.56 b	605.28 a
CS							
RF	39.57 c	15.71 b	3.67 a	5.43 c	125.33 a	77.98 c	599.72 a
B	38.35 b	18.11 c	2.95 b	3.99 b	126.72 a	59.36 b	587.22 a
CSIS	35.41 a	13.41 a	2.66 a	3.31 a	134.39 b	52..72 a	583.89 a

In terms of NQCF and incorporation of plant residues, the difference between the 2 sowing systems is insignificant. The values of this indeces are highest in the variants with RF and B when using CS. In these variants, however, TS leads to their increase and the excess compared to CS is respectively 9.88% and 4.16%. Thus, on average, for the tested ways of using plant residues, the traditional method of sowing exceeds the sowing with a combined machine system by an average of 4.90%. As already mentioned, the volume of bread, regardless of the established differentiation in values, is statistically unreliable.

What makes an impression is that in different systems the meteorological factor affects the values of the tested quality characteristics with different strength (Figure 2). Its independent influence on TS has a determining power of impact on the indicators DS f.u., LVol, WGC, SD and SED, which varies from 95.85% to 12.84%, respectively. The type of plant residue of the predecessor has a determining force on the values of DD at TS. The power of the ways of using plant residues is well expressed on the values of SD, DD and NQCF, but still this is the factor whose power of influence on the quality characteristics of the variety is less pronounced compared to the independent action of the other two (*Year and Predecessor*). A similar tendency, for the leadership influence of the meteorological factor, was also found for CS, where the variation in the impact strength was 86.68% DS f.u. to 2.18% (SED). The strength of the independent influence of the type of plant residue of the predecessor is greatest in SED (14.36%), and in the way of their use - NQCF (19.81%).

Of all the types of combined interactions, the strongest in its impact is the *Year x Predecessor* combination. The strength of its impact varies from 74.06% SED to 2.18% DS f.u. This tendency is also preserved for TS, but the strength of the indicated combined interaction is weaker - from 48.27% SED to 1.05% NQCF.

On average for the research period, regardless of the seeding machine systems used, the type of plant residues of the predecessor has a significant influence on the tested parameters characterizing the quality of flour, dough and bread (Figure 3).

Sedimentation and wet gluten content had the highest values after the maize PHR.

Although with an unreliable difference between the predecessors, this trend is also observed for the volume of bread. For the rheological properties of the flour, plant residues from the precursor bean had a stronger positive influence compared to those from sunflower and maize.

The use of the plant residues of the predecessor in the three ways indicated affects the wide range of quality indicators of the produced production. Cleaning the field of residues has a positive effect on sedimentation (SED), development (DD-min) and dough stability (SD-min) as well as on the degree of its softening (DS f.u.). For the study period, these indeces have higher average values compared to the other two ways of using plant residues.

The annual burning of plant residues is an extremely inadvisable agrotechnical practice, because affects the environment as a whole. Here, our attention is focused on some technological and baking qualities of wheat. Its influence on some rheological properties of the dough - stability and degree of softening of the dough (SD and DS f.u.), as well as on the values of the number of the quality factor (NQCF) is extremely unfavorable. A similar tendency is observed in other indicators, where it occupies an intermediate position. Only in this variant were the highest average values of wet gluten yield (WGC) reported.

The number of the quality coefficient (NQCF) as one of the most important quality characteristics shows that, on average for the period, the Enola variety achieves the highest values precisely when the plant residues are returned to the soil. The influence of this way of using the plant residues was definitely negative for the values of the indeces of sedimentation (SED) and yield of wet gluten (WGC).

In each of the research years, significant dynamics were found in the values of the correlation dependences between the tested quality indicators and the level of their statistical reliability (Table 6). In the year with the most favorable conditions for the development of wheat during the studied period (2017), the SED is in a clearly expressed positive relationship with the DD and with its stability (SD) and degree of softening DS f.u. in both tested systems seeding machines. This index is also highly correlated with the WGC in CS. The yield of wet gluten in the grain (WGC) shows a well-expressed differentiation in its correlative dependences with the other parameters in the tested systems of sowing machines. The use of CS was distinguished by higher values of correlation coefficients in the relationship between SED with DD and LVol compared to traditional sowing (TS). When using the latter, however, the relationship between WGC with dough stability (SD) and degree of softening

DS f.u. is stronger compared to that found with CS. It can be seen that the relationship between DD time and its stability and degree of softening is pronounced in both seeding systems, but the correlation values are higher when using TS compared to CS.

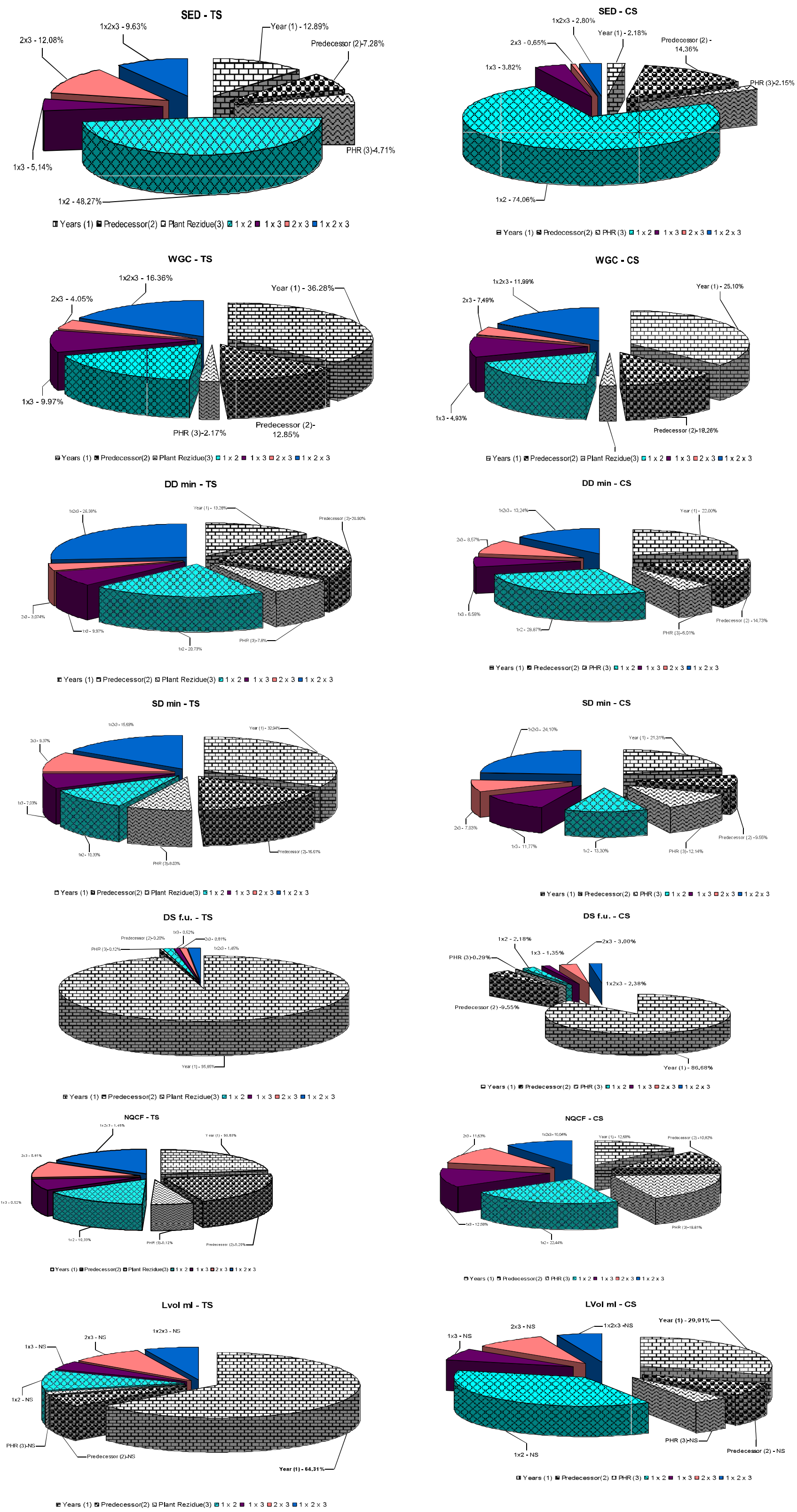
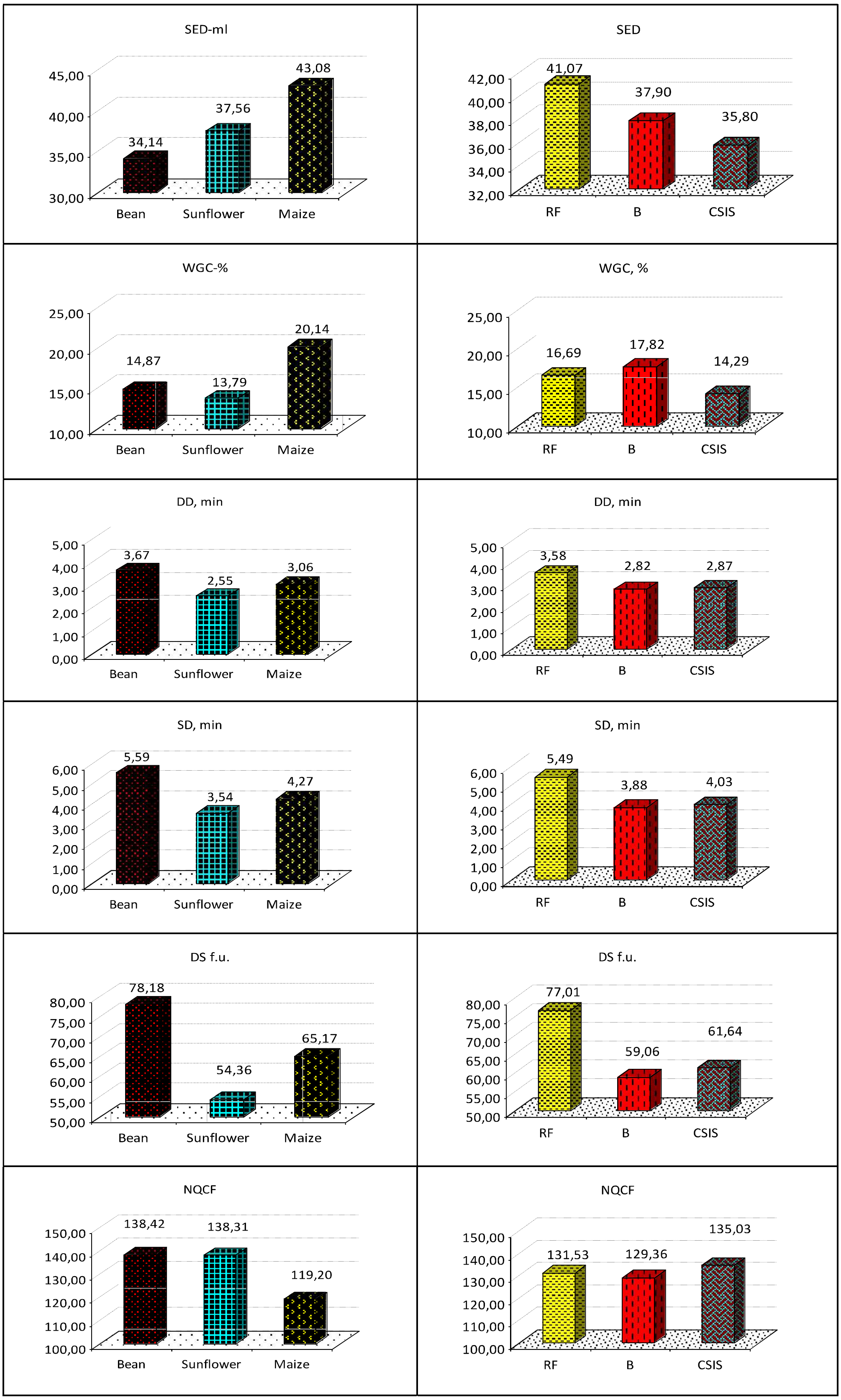


Figure 2. Strength of effect of the factors and their combinations average for the period 2017-2019 on the bread making qualities of wheat according to sowing systems


SED-ml
45,00
40,00
35,00
30,00
34,14
37,56
43,08
Bean
Sunflower
Maize
SED
42,00
40,00
38,00
36,00
34,00
32,00
41,07
37,90
35,80
RF
B
CSIS
WGC-%
25,00
20,00
15,00
10,00
14,87
13,79
20,14
Bean
Sunflower
Maize
WGC, %
25,00
20,00
15,00
10,00
16,69
17,82
14,29
RF
B
CSIS
DD, min
5,00
4,00
3,00
2,00
1,00
0,00
3,67
2,55
3,06
Bean
Sunflower
Maize
DD, min
5,00
4,00
3,00
2,00
1,00
0,00
3,58
2,82
2,87
RF
B
CSIS
SD, min
6,00
5,00
4,00
3,00
2,00
1,00
0,00
5,59
3,54
4,27
Bean
Sunflower
Maize
SD, min
6,00
5,00
4,00
3,00
2,00
1,00
0,00
5,49
3,88
4,03
RF
B
CSIS
DS f.u.
80,00
75,00
70,00
65,00
60,00
55,00
50,00
78,18
54,36
65,17
Bean
Sunflower
Maize
DS f.u.
80,00
75,00
70,00
65,00
60,00
55,00
50,00
77,01
59,06
61,64
RF
B
CSIS
NQCF
150,00
140,00
130,00
120,00
110,00
100,00
138,42
138,31
119,20
Bean
Sunflower
Maize
NQCF
150,00
140,00
130,00
120,00
110,00
100,00
131,53
129,36
135,03
RF
B
CSIS

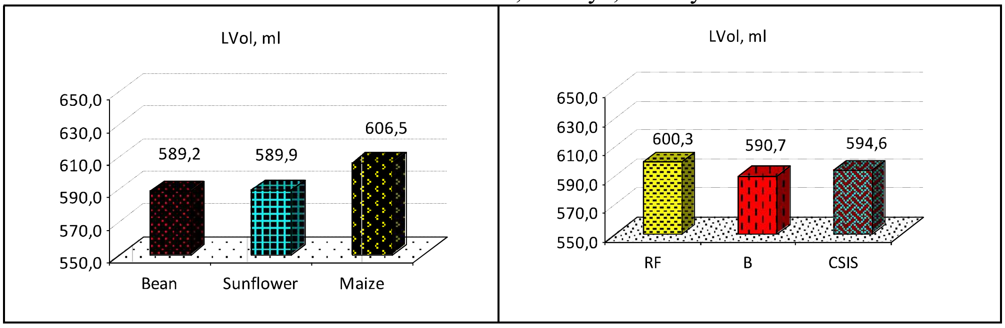


Figure 3. Average values for the quality characteristics of flour, dough and bread of the Enola variety depending on the type of plant residue and ways of their use, 2017-2019

The highest level of positive correlation in 2017 was found between dough stability (SD) and degree of softening (DS f.u.) - 0.983** (TS) and 0.953** (CS).

The number of quality coefficient (NQCF) is in a very well expressed positive correlation with the volume of bread (LVol) when using TS (0.719**), and when using CS the relationship is negative (-0.528*). For this index, no statistically reliable correlations with the other investigated quality indicators have been established. Under the conditions of water deficit for the growing season, accompanied by extreme droughts in critical phases of development (2018), the positive correlation between SED and WGC is most pronounced in both systems, respectively 0.910** (TS) and 0.922** (CS), followed by that of DD and DS f.u. This tendency holds true for both seeding systems tested. When applying traditional seeding, high levels of positive correlation between the WGC and the degree of softening of the dough (DS f.u.) - 0.872**, as well as with its stability - 0.854** and its development time - 0.597 **. The correlation between SD and NGCF was strongly negative for both seeding systems. A similar negative correlation distinguishes the relationship between the NGCF and the degree of softening of the dough (DS f.u.).

The results show that the volume of bread (LVol) in traditional sowing is in most cases negatively correlated with most of the quality indicators, and statistically unreliable. Only in the case of sowing with a combined machine system, statistical reliability was established with the flour sedimentation (SED - 0.472*) and the number for the quality factor (NGCF-0.511*).

In 2019, statistically significant correlation dependencies are much less compared to the other two years and at a relatively lower level of correlation coefficient values. The most significant is that between SD) and DS f.u. - respectively for TS seeding 0.994** and CS seeding 0.968**. In the next position are the correlations between SED and dough stability (TS - 0.836** and CS-0.846**), as well as between SED and the degree of softening of dough (TS - 0.828** and CS -0.748**). A positive correlation with the bread volume indicator (LVol) was found only with the yield of wet gluten in the flour under a traditional sowing system (0.657**).

The correlation dependences averaged over the study period for each of the systems separately show a very strong correlation between the stability of the dough and the number for its quality, regardless of the system of machines for soil preparation and sowing (Figure 4). A similar trend is observed in the correlation dependences between the SED and the WGC. The correlation coefficients between the degree of softening of the dough (DS f.u.) with the DD with all the other quality indicators in both machine systems, the correlations were negative. Loaf volume (LVol) correlated strongly negatively with DS f.u. and positively with dough stability (SD), especially in the TS.

Table 6. Pearson Correlations between quality indices according to systems of sowing by years of investigation (n=18)

Indices	SED		WGC		DD		SD		NGCF		DS f.u.		LVol	
	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS	TS	CS
2017														
SED	1	1	0.485*	0.789**	0.837**	0.876**	0.726**	0.783**	0.056	-0.038	0.732**	0.822**	0.001	0.424
WGC	0.485*	0.789**	1	1	0.582*	0.701**	0.633**	0.447	0.465	-0.331	0.683**	0.485*	0.504*	0.659**
DD	0.837**	0.876**	0.582*	0.701**	1	1	0.858**	0.611**	0.107	0.040	0.841**	0.695**	0.344	0.201
SD	0.726**	0.783**	0.633**	0.447	0.858**	0.611**	1	1	0.111	-0.079	0.983**	0.953**	0.373	0.266
NGCF	0.056	-0.038	0.465	-0.331	0.107	0.040	0.111	-0.079	1	1	0.226	-0.065	0.719**	-0.528*
DS f.u.	0.732**	0.822**	0.683**	0.485*	0.841**	0.695**	0.983**	0.953**	0.226	-0.065	1	1	0.452	0.336
LVol	0.001	0.424	0.504*	0.659**	0.344	0.201	0.373	0.266	0.719**	-0.528*	0.452	0.336	1	1
2018														
SED	1	1	0.910**	0.922**	0.722**	0.565*	0.616**	0.172	-0.261	0.243	0.767**	,486(*)	-0.045	0.472*
WGC	0.910**	0.922**	1	1	0.681**	0.676**	0.854**	0.250	-0.469*	0.044	0.872**	,637(**)	-0.109	0.360
DD	0.722**	0.565*	0.681**	0.676**	1	1	0.597**	0.337	-0.464	-0.386	0.818**	,846(**)	-0.161	-0.073
SD	0.616**	0.172	0.854**	0.250	0.597**	0.337	1	1	-0.790**	-0.630**	0.895**	,665(**)	-0.127	-0.171
NGCF	-0.261	0.243	-0.469*	0.044	-0.464	-0.386	-0.790**	-0.630**	1	1	-0.648**	-,668(**)	0.367	0.511*
DS f.u.	0.767**	0.486*	0.872**	0.637**	0.818**	0.846**	0.895**	0.665**	-0.648**	-0.668**	1	1	-0.095	-0.210
LVol	-0.045	0.472*	-0.109	0.360	-0.161	-0.073	-0.127	-0.171	0.367	0.511*	-0.095	-,210	1	1
2019														
SED	1	1	0.636**	0.416	0.375	0.581*	0.836**	0.846**	-0.265	0.599**	0.828**	0.748**	0.430	0.165
WGC	0.636**	0.416	1	1	0.310	0.217	0.286	0.013	0.020	0.015	0.321	-0.080	0.657**	0.462
DD	0.375	0.581*	0.310	0.217	1	1	0.409	0.500*	0.535*	0.674**	0.416	0.431	0.378	0.378
SD	0.836**	0.846**	0.286	0.013	0.409	0.500*	1	1	-0.406	0.597**	0.994**	0.968**	0.162	0.107
NGCF	-0.265	0.599**	0.020	0.020	0.535*	0.674**	-0.406	0.597**	1	1	-0.424	0.482*	0.137	0.121
DS f.u.	0.828**	0.748**	0.321	-0.080	0.416	0.431	0.994**	0.968**	-0.424	0.482*	1	1	0.179	0.076
LVol	0.430	0.165	0.657**	0.462	0.378	0.378	0.162	0.107	0.137	0.121	0.179	0.076	1	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

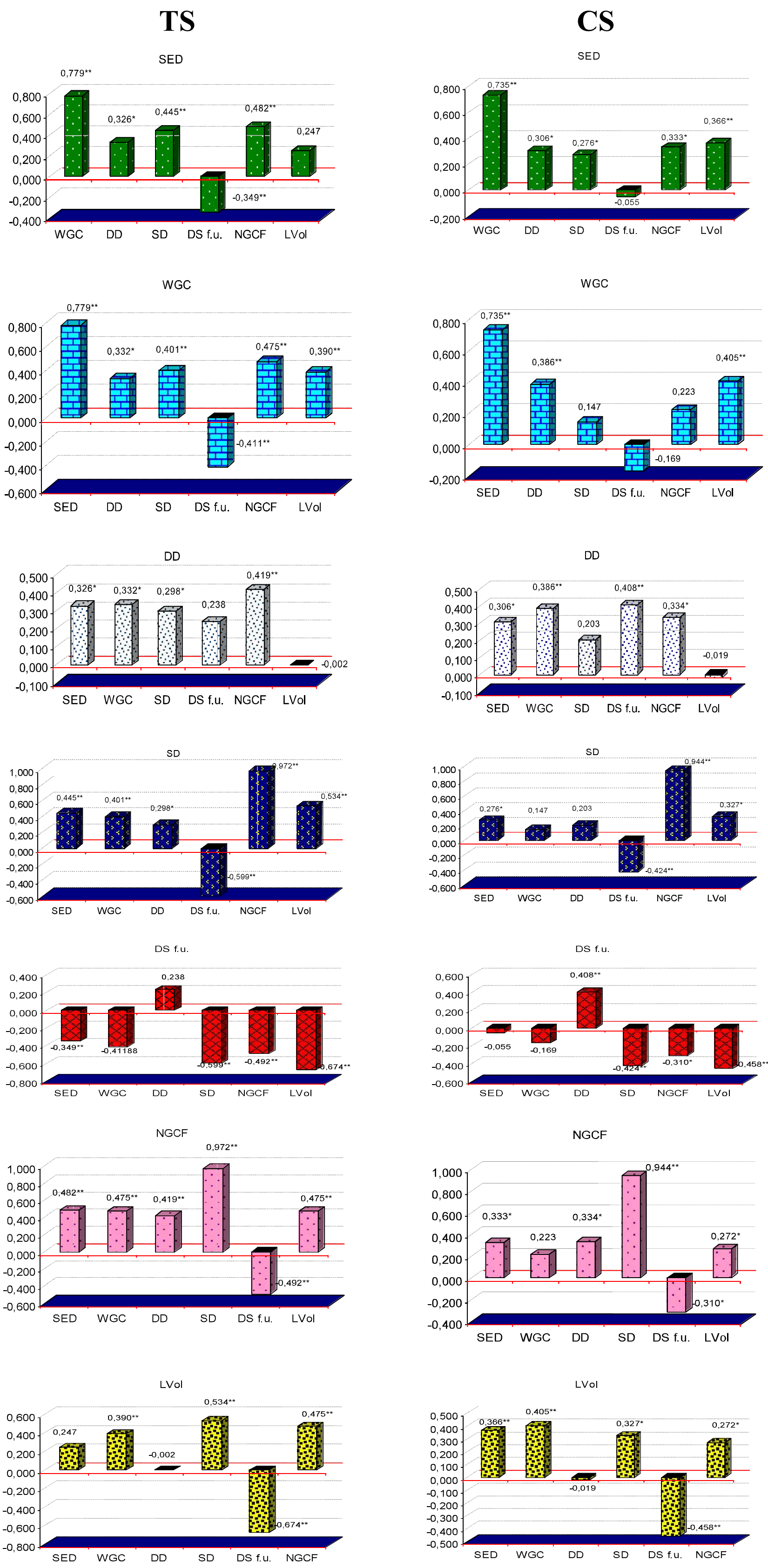


Figure 4. Pearson Correlations between quality indices average for 2017-2019 (n=54)

CONCLUTIONS

The present study gives us the opportunity to obtain information about the dynamics in the values of a number of quality characteristics of flour and dough as a result of the influence of current agrotechnical practices with a main emphasis on the ways of using different plant residues of wheat predecessors.

The beans PHR under both soil preparation and sowing systems was found to increase farinographic stability (SD) and dough development time (DD), degree of softening (DS f.u.) and flour quality coefficient number (NQCF). Except for the softening degree data, the traditional system contributes higher data values for the listed indicators than the combined system. Sedimentation and wet gluten content were highest after maize precursor and again in traditional system (TS).

The removal of plant residues from the field in both sowing systems leads to an increase in the values of flour sedimentation, dough stability, especially rheological properties, as well as the yield of wet gluten in the grain in the traditional sowing system. Conversely, incorporation the PHR into the soil is the reason for the noticeable decrease in the values of these indeces. In a combined sowing system, however, the inclusion of the entire amount of the non-economic part of previous production leads to an increase in the values of the degree of softening. It was also found that the burning of the post-harvest residues in the combined system provoked the obtaining of higher wet gluten values in the grain and increased the dough development time.

Irrespective of weather conditions, the correlative dependences between flour sedimentation value (SED) and wet gluten yield (WGC), its development time (DD), its stability (SD) and degree of softening (DS f.u.) are most stably expressed. This tendency is more pronounced with traditional seeding for the area compared to the use of the combined system of seeding machines.

Bread volume is the quality characteristic that is practically not significantly affected by the way of using the post-harvest residues and by its interactions with other factors in both tested systems. Its values in both systems are mainly influenced by the meteorological factor, and this fact applies to a much greater extent to traditional sowing compared to that with a combined system of machines.

The years with an optimal combination of the main meteorological elements (2017) have a significant contribution to obtain higher values for sedimentation, wet gluten and the number for the quality coefficient. In years with insufficient rainfall combined with higher temperatures in critical phases of the perennial wheat vegetation (2018), the dough development time and degrees of softening were higher compared to the others.

Multiple correlations were established between the tested quality characteristics by years of research and average over the period. They differ both in the direction of interaction and in the strength of the correlation dependences by sowing systems.

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