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Improvement of physical, physicochemical, and rheological characteristics of sunn pest (*Eurygaster integriceps*) damaged wheat by blending

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RESEARCH ARTICLE

Abstract

This study was undertaken to investigate the effects of blending to improve the physical, physicochemical, and rheological characteristics of high level sunn pest damaged wheat (HLSPDW). HLSPDW (20.6%) variety (Sagittario) was blended at seven different levels with the sound wheat (SW) of same variety. When HLSPDW was blended with SW, the harm of sunn pest was relatively reduced. With an increasing SW portion in the blend, also physical, physicochemical, and rheological characteristics of wheat increased. The HLSPDW used in blending was found more decisive than SW in determination of the wheat, flour, and dough quality. Therefore, one has to be very careful about the ratio of HLSPDW mass used in the blending process. Otherwise, an SW sample could be wasted through blending with HLSPDW. The blending treatment alone is insufficient for improving the quality of HLSPDW, however this technique can be implemented in combination with some other methods such as using additives in bread-making.

Keywords: blending, bread wheat, optimum blending ratio, sunn pest, wheat quality

1. Introduction

Sunn pest (SP, *Eurygaster integriceps* Puton), is one of the most important pests of wheat in Western and Central Asia. SP, known in Turkey since 1927, causes large damage particularly in south and south-eastern Anatolia. Both nymphs and adults of this species have been linked to plant damage, where they feed on leaves, stems, and grains of cereals (Critchley, 1998; Lodos, 1982).

The unique characteristic of sunn pest damaged wheat (SPDW) is a disrupted protein structure due to the action of some injected proteinases (Kretovich, 1944). SPDW reduces the flour quality (Karababa and Ozan, 1998), giving a softer dough and subsequently flat bread with low volume and unsatisfactory texture (Hariri *et al.*, 2000; Lorenz and Meredith, 1988a). There is great difficulty in making bread from SPDW flour for millers and bakers (Dizlek and Gul, 2007). Various studies have tried improving SPDW and wheat flour quality (Atli *et al.*, 1988a,b; Bonet *et al.*, 2005; Caballero *et al.*, 2005a,b; Diraman, 2010; Diraman and Atli, 2005; Diraman and Demirci, 1997; Diraman *et al.*, 2013; Dizlek and Özer, 2010; Dizlek *et al.*, 2008a; Elgun *et al.*, 1992; Ertugay *et al.*, 1995; Köksel *et al.*, 2001, 2002; Matsoukas and Morrison, 1990; Ozkaya *et al.*, 1990; Sivri and Köksel, 1996; Tuncer *et al.*, 2002; Turker and Elgun, 1998; Unal *et al.*, 1993). Among these, the principal applications, heat and hydrothermal treatments prior to milling such as tempering with (hot) water or steam, application of low dosage radiation and short time microwave to tempered SPDW, and blending with strong and sound wheat (SW) samples were studied. Beside these, the use of inhibitors to inactivate protease activity in the dough, and/or use of additives to increase the quality and quantity of gluten during the dough preparing stage, application of short processing time, changing pH, water activity, temperature, and dough consistency to limit the activity of protease are other methods used to improve bread made from SPDW flours (Dizlek and Gul, 2007).

It has been reported that SP damage could relatively be reduced by mixing (blending) the damaged wheat with quality wheat (hard, strong, and sound [healthy]) at specific ratios (Atli *et al.*, 1988b; Diraman *et al.*, 1998; Ozkaya and

Ozkaya, 1993; Unal *et al.*, 1993). In general, commercial millers are required to apply a blending process; an important step of milling technology, by mixing wheat cultivars of different qualities in order to produce flour of the quality desired by the bakers and according to the standards. Blended wheat cultivars comprise superior properties and mixing is widely used by millers in many countries (Kocak *et al.*, 1993). Different researchers (Hatcher *et al.*, 2008, 2009; Hook, 1983; Kocak, 1988; Turker and Elgun, 1997) studying the blending process have revealed that blending has a positive impact in the milling/cereal industry as long as it is carried out carefully and properly.

The present study aimed to improve the quality of very high level (20.6%) sunn pest damaged wheat (HLSPDW) (i.e. a quality used as animal feed) by blending in order to increase the economic value of this wheat. Determining the optimum blending ratios to achieve the best wheat quality and obtaining practical information for millers in the light of scientific data were other objectives of this study. Therefore, we studied the important quality parameters of seven different blended wheat groups in terms of bread-making.

2. Materials and methods

Wheat samples

In this study, two samples (SP damaged and undamaged) belonging to the same cultivar (Sagittario) were used. Insect damaged and undamaged wheat samples purchased from Koca Agricultural Products (Salbas-Karaisali, Adana, Turkey) and Savrunlar Milling Factory (Adana, Turkey) Companies, respectively. Totally, one hundred SP samples were collected from damaged wheat bulk. The SP species were determined by a scientist from Agricultural Protection Research Institute (Adana, Turkey) specialised in identification of insect species; 99% of the damaged kernels were caused by *E. integriceps* and the remaining 1% by *Eurygaster maura*. For the determination of the SP damaged kernel ratio of both wheat samples, ten sets of 100 kernels were separated randomly from the each sample. The number of damaged kernels by SP in each set was recorded and % damage ratio was reported as the average of ten measurements (Atli *et al.*, 1988a). The SP damage ratio was 20.6 and 0% for damaged and undamaged wheat, respectively.

Preparation of blending groups

Seven wheat groups were prepared as follows: SPDW and SW samples were blended manually at different levels (100-0%, 50-50%, 40-60%, 30-70%, 20-80%, 10-90%, and 0-100%). Then, each wheat group was mixed thoroughly so that it was homogeneous within itself (these groups were used in physical analyses). After that, the prepared blends were tempered to 16.5% moisture content for 32 h and milled separately with a laboratory type mill (Yucebas YM1 model tempered wheat grinding mill, including six rolls; Yucebas Machine, Izmir, Turkey) to determine the physicochemical (technological) characteristics of wheat flours and rheological characteristics of dough samples. Finally, the milled flour samples were rested for one month at 20 °C for ripening and then used in physicochemical and rheological analyses.

Measurement of physical properties of wheat blends

Main physical, physicochemical, and rheological analyses were applied for the seven wheat groups. According to Uluoz (1965) thousand kernel weight, hectolitre weight, and kernel vitreousness of the wheat groups were assigned. Kernel size distribution was determined according to Williams *et al.* (1986). In order to determine the kernel size distribution of wheat samples, after removal of foreign matters, 100 g wheat sample was sifted for 3 min through sieves with sizes of 2.8, 2.5, and 2.2 mm, respectively ('Steinecker' sieve set). Then, the amount of wheat on each sieve was weighed, and the rates determined. The wheat samples with consecutive on-sieve rates of +75% were considered as homogenous (Elgun *et al.*, 1998).

Measurement of physicochemical properties of wheat flour groups

Wheat flour groups were objected to a Zeleny sedimentation test (AACCI Method 56-60.01, AACCI, 2000), delayed Zeleny sedimentation test (Greenaway *et al.*, 1965), wet and dry gluten content (AACCI Method 38-10.01, AACCI, 2000), gluten index value (AACCI Method 38-12.02, AACCI, 2000), delayed gluten index value (Aja *et al.*, 2004), and falling number value (AACCI Method 56-81.03, AACCI, 2000) in order to determine important technological characteristics of bread wheat. The flour samples were incubated for 2 h at 30 °C in the Zeleny sedimentation test tube after the addition of brome phenol blue solution to allow proteolytic reactions occurring in delayed Zeleny sedimentation test. Standard time (0 min) in gluten index was extended to 120 min in delayed gluten index (wet gluten samples were put in gluten index machine after the 2 h resting for the determination of delayed gluten index value).

Measurement of rheological properties of wheat flour groups

AACCI Approved Method 54-21.02 (AACCI, 2000) was followed to determining of farinograph properties (water absorption, dough development time, stability, tolerance index, and softening degree) of the wheat flour groups. A 300 g mixing bowl was used. The AACCI Approved Method 54-10.01 (AACCI, 2000) was used for extensograph studies. Resistance to extension (R_5), maximum resistance to extension (R_{max}), extensibility, and energy values were detected at 45, 90, and 135 min. In this study, the 'dokaj' process was not applied to any of the wheat groups. Blending groups (50-50%, 40-60%, 30-70%, 20-80%, and 10-90%) and the SW group (0-100%) were compared with SPDW group (100-0% = control). All analytical results were corrected to 14% moisture basis.

Statistical analysis

All analyses were carried out in three replicates. Analyses of variance (ANOVA) was conducted by using SAS (SAS Institute, Cary, NC, USA). When a significant difference was found between the treatments, Duncan's multiple range tests were performed to determine the differences among the mean values (P<0.05).

3. Results and discussion

Individual properties of wheat samples used in blending application and the effects of various levels blending of SPDW and SW samples on physical characteristics of wheat are given in Table 1 and 2. The technological characteristics of (wheat) flour are provided in Table 3, and rheological characteristics of flour and dough are presented in Table 4 and 5. When wheat blending is used, each wheat mass used for blending should be well characterised (Dizlek and Gul, 2007). Therefore, we first present the results and discuss the individual properties of the wheat samples used for blending.

The basic material of the study, Sagittario cultivar SPDW sample (100-0%), had very high SP damage ratio (20.6%). This state, naturally, led to the too low bread quality for this sample (Table 1-5). Thousand kernel and hectolitre

Table 1. The effect of various levels blending of sunn pest damaged wheat (SPDW) and sound wheat (SW) samples on some physical characteristics of wheat's (blending groups) (n=3). [1]

Blending ratio[2] (SPDW%-SW%)	Sunn pest damaged grain ratio (%)	Hectolitre weight (kg)	Thousand kernel weight (g)[3]	Vitreous kernel ratio (%)	Translucent kernel ratio (%)	Mealy kernel ratio (%)
100-0 (control)	20.6^{a}±0.3	72.5^{f}±0.2	30.2^{g}±0.3	24±5	69±3	7±4
50-50	10.3^{b}±0.2	76.0^{e}±0.5	34.2^{f}±0.1	26±4	68±3	6±3
40-60	8.24^{c}±0.2	76.7^{de}±0.6	35.1^{e}±0.1	22±5	70±2	8±3
30-70	6.18^{d}±0.1	77.3^{d}±0.5	35.9^{d}±0.2	24±3	66±3	10±3
20-80	4.12^{e}±0.2	78.0^{c}±0.4	36.7^{c}±0.1	25±5	68±3	7±3
10-90	2.06^{f}±0.1	78.7^{b}±0.2	37.6^{b}±0.2	23±4	67±3	10±2
0-100	0^{g}±0	79.4^{a}±0.2	38.4^{a}±0.1	25±4	68±3	7±4

[1] Mean values in the table for the same column shown with the different superscript letter are significantly different (P<0.05).
[2] First value of the blending ratio represents 20.6% SPDW sample and the second represents the undamaged SW sample in the blending portion.
[3] Calculations are based on the dry matter basis.

Table 2. The effect of various blending levels of sunn pest damaged wheat (SPDW) and sound wheat (SW) samples on kernel size distribution values (%) (n=3).[1]

Blending ratio [2] (SPDW%-SW%)	Large (≥2.8 mm)	Medium (2.5-2.8 mm)	Small (2.2-2.5 mm)	Undersize (≤2.2 mm)	Largeness-homogeneity
100-0 (control)	33.8^{g}±0.3	35.2^{a}±0.2	22.6^{a}±0.3	8.4^{a}±0.3	heterogeneous
50-50	41.6^{f}±0.3	33.8^{b}±0.3	18.4^{b}±0.5	6.2^{b}±0.3	large-homogeneous
40-60	43.1^{e}±0.2	33.5^{b}±0.4	17.6^{b}±0.5	5.8^{b}±0.4	large-homogeneous
30-70	44.5^{d}±0.3	33.2^{bc}±0.3	16.9^{bc}±0.4	5.4^{bc}±0.3	large-homogeneous
20-80	46.2^{c}±0	32.9^{bc}±0.3	16.0^{c}±0.5	4.9^{bc}±0.3	large-homogeneous
10-90	47.9^{b}±0.1	32.6^{c}±0.3	15.1^{d}±0.3	4.4^{c}±0.4	large-homogeneous
0-100	49.6^{a}±0.2	32.2^{c}±0.3	14.4^{d}±0.5	3.8^{c}±0.4	large-homogeneous

[1] Mean values in the table for the same column shown with the different superscript letters are significantly different (P<0.05).
[2] First value of the blending ratio represents 20.6% SPDW sample and the second represents the undamaged SW sample in the blending portion.

Table 3. The effect of various levels blending of sunn pest damaged wheat (SPDW) and sound wheat (SW) samples on technological characteristics of flour samples (n=3).[1]

Blending ratio[2] (SPDW%-SW%)	Zeleny sedimentation value[3] (ml)	Delayed Zeleny sedimentation value[3,4] (ml)	Wet gluten content (%)	Dry gluten content (%)	Gluten index value (%)	Delayed gluten index value[4] (%)	Falling number value (s)
100-0 (control)	$29.9^{e}\pm0.3$	$4.6^{g}\pm0.1$	$33.0^{a}\pm0.2$	$11.0^{a}\pm0.1$	$0^{f}\pm0$	$0^{d}\pm0$	$277^{e}\pm5$
50-50	$33.5^{d}\pm0.4$	$8.0^{f}\pm0.1$	$31.4^{b}\pm0$	$10.5^{b}\pm0.1$	$34^{e}\pm1$	$0^{d}\pm0$	$318^{d}\pm5$
40-60	$36.0^{c}\pm0.2$	$10.5^{e}\pm0.2$	$31.1^{c}\pm0.1$	$10.4^{bc}\pm0$	$56^{d}\pm2$	$0^{d}\pm0$	$329^{cd}\pm4$
30-70	$36.0^{c}\pm0.4$	$14.0^{d}\pm0.1$	$30.6^{d}\pm0.2$	$10.2^{c}\pm0.1$	$84^{c}\pm2$	$0^{d}\pm0$	$332^{c}\pm2$
20-80	$38.0^{b}\pm0.4$	$16.0^{c}\pm0.2$	$29.9^{e}\pm0.2$	$10.0^{d}\pm0$	$90^{b}\pm2$	$1^{c}\pm0$	$345^{b}\pm5$
10-90	$37.5^{b}\pm0.3$	$28.0^{b}\pm0.3$	$29.9^{e}\pm0.1$	$10.0^{d}\pm0$	$98^{a}\pm2$	$45^{b}\pm2$	$356^{ab}\pm4$
0-100	$39.0^{a}\pm0.2$	$46.0^{a}\pm0.5$	$29.2^{f}\pm0.1$	$9.8^{e}\pm0$	$99^{a}\pm1$	$96^{a}\pm4$	$361^{a}\pm3$

[1] Mean values in the table for the same column shown with the different superscript letter are significantly different (*P*<0.05).
[2] First value of the blending ratio represents 20.6% SPDW sample and the second represents the undamaged SW sample in the blending portion.
[3] Adjusted to 14% moisture basis.
[4] For the determination of effects of sunn pest protease clearly delaying made 2 h.

Table 4. The effect of various levels blending of sunn pest damaged wheat (SPDW) and sound wheat (SW) samples on farinogram values of flour samples (n=3).[1]

Blending ratio[2] (SPDW%-SW%)	Water absorption (%)	Dough development time (min)	Stability (min)	Tolerance index (BU)[3]	Softening degree (BU)[3]
100-0 (control)	$61.6^{a}\pm0.1$	$2.1^{g}\pm0.1$	$2.3^{g}\pm0.1$	$212^{a}\pm7$	$278^{a}\pm14$
50-50	$59.4^{f}\pm0.1$	$3.2^{f}\pm0$	$4.0^{f}\pm0.1$	$116^{b}\pm7$	$188^{b}\pm10$
40-60	$60.0^{e}\pm0$	$3.3^{e}\pm0$	$4.5^{e}\pm0$	$96^{c}\pm4$	$192^{b}\pm11$
30-70	$60.2^{d}\pm0$	$3.8^{d}\pm0.1$	$4.7^{d}\pm0.1$	$82^{d}\pm3$	$144^{c}\pm10$
20-80	$60.8^{c}\pm0.1$	$4.9^{c}\pm0$	$5.5^{c}\pm0.1$	$69^{e}\pm2$	$115^{d}\pm6$
10-90	$61.2^{b}\pm0.1$	$6.0^{b}\pm0$	$7.0^{b}\pm0.1$	$69^{e}\pm3$	$94^{e}\pm5$
0-100	$61.1^{b}\pm0$	$7.1^{a}\pm0.1$	$9.8^{a}\pm0.2$	$55^{f}\pm4$	$98^{e}\pm6$

[1] Mean values in the table for the same column shown with the different superscript letter are significantly different (*P*<0.05).
[2] First value of the blending ratio represents 20.6% SPDW sample and the second represents the undamaged SW sample in the blending portion.
[3] Brabender units.

Table 5. The effect of various levels blending of sunn pest damaged wheat (SPDW) and sound wheat (SW) samples on extensogram values of flour samples (n=3).

Blending ratio[1] (SPDW%-SW%)	R_5 (resistance to extension, 5 cm) (BU)[2]			R_{max} (maximum resistance to extension) (BU)[2]			Extensibility (mm)			Energy (cm^2)		
	45.'	90.'	135.'	45.'	90.'	135.'	45.'	90.'	135.'	45.'	90.'	135.'
100-0 (control)	Could not be drawn			Could not be drawn			Could not be drawn			Could not be drawn		
50-50	Could not be drawn			Could not be drawn			Could not be drawn			Could not be drawn		
40-60	Could not be drawn			Could not be drawn			Could not be drawn			Could not be drawn		
30-70	57±1	Could not be drawn		59±2	Could not be drawn		122±1	Could not be drawn		12±0	Could not be drawn	
20-80	98±3	96±4	79±4	106±4	99±2	81±3	161±2	132±4	94±1	30±1	24±1	16±0
10-90	163±4	197±5	191±7	205±5	214±4	204±5	161±3	132±2	123±3	54±1	49±1	43±0
0-100	255±7	365±9	441±7	341±8	448±9	488±9	165±3	132±2	117±2	83±2	88±1	88±1

[1] First value of the blending ratio represents 20.6% SPDW sample and the second represents the undamaged SW sample in the blending portion.
[2] Brabender units.

weight of the control sample was 30.2 g and 72.5 kg, respectively (Table 1). It was clear that the high levels of SP damage caused these low values. By examining the value of grain hardness (Table 1), the dominant group in the wheat mass was composed of translucent grains; this character was thought mainly to be affected by the environment (Atli, 1985). The control sample had a medium kernel size distribution and a heterogeneous structure (Table 2). Evaluating foreign material content (data not shown) and hectolitre weight data (Table 1) together, the control sample was determined as 'off-grade' according to TS 2974 wheat standard (TSE, 2003). Some studies reported that this type of high level SPDW wheat could be used as animal feed (Kinaci and Kinaci, 2004; Lorenz and Meredith, 1988a; Sinangil, 1992; Sivri *et al.*, 2004; Turker, 1998; Yuksel, 1969). The physical properties of the control sample also determined the sample as 'off-grade' wheat, thereby reinforcing the previous finding.

Thousand kernel and hectolitre weights are important quality features for determining the suitability of wheat for milling. Thousand kernel weights are positively correlated with flour yield. Soundness of the grain also directly influences flour quality and flour yield (Karababa and Ozan, 1998). Vitreousness is an important property in the grading of wheat (Bushuk, 1998).

As expected, a great difference was found between the sedimentation and delayed sedimentation values of flour of the control sample (Table 3; Dizlek and Islamoglu, 2015). Amount of wet and dry gluten were found to be high (33 and 11%, respectively), whereas the gluten index value was 0% indicating that the control sample had a high gluten quantity but a too weak gluten quality. This finding was consistent with other studies (Atli *et al.*, 1988a,b; Diraman, 2009; Every *et al.*, 1990; Greenaway *et al.*, 1965; Lorenz and Meredith, 1988a,b; Perez *et al.*, 2005; Redman, 1971; Rosell *et al.*, 2002) who reported damage of SP and other insects (*Aelia*, *Nysius huttoni,* etc.) having the same effect; i.e. affecting cereals protein quality rather than protein quantity. Amylase activity of the control flour group was found high due to the intensive SP damage (Atasanova and Popova, 1968; Dizlek *et al.*, 2008b; Kretovich, 1944; Lorenz and Meredith, 1988b). The amylase activity of the control was close to the desired falling number value for bread flour (250±25 s). Thus, this flour had almost ideal amylase activity value (Table 3). It was found that dough development and stability time of flour sample of control flour were low, whereas tolerance index and softening degree values were very high (Table 4). These results indicated that the quality of flour was weak (Williams *et al.*, 1986). As a natural consequence of wheat affected by excess SP damage, the protein quality of the flour declined very dramatically and this state is shown by the extensograph drawing (Table 5). At 45 min, dough overflow was outward from banquet, widely spread, and showed a tendency to break. The dough could not be drawn as it could not adhere to the hook of extensograph device. As expected, drawings at 90 and 135 min were also not possible for these groups. Also Dizlek and Özer (2016, 2017) found that extensograph measurements could not be drawn at high blending ratio.

Zeleny and delayed Zeleny sedimentation tests, wet and dry gluten content, and gluten index values (normal and delayed) were carried out for the determination of the effect of SP damage on the physicochemical characteristics of wheat flour samples. Especially the delayed Zeleny sedimentation test, as improved by Greenaway *et al.* (1965), was found suitable for the detection of SP damage in wheat flour (Diraman, 2010; Dizlek and Islamoglu, 2015). The gluten index value is defined as the percentage of wet gluten remaining on the sieve after automatic washing in a salt solution and centrifugation; it is a fast method to analyse gluten attributes, indicating whether the gluten is weak, normal or strong (Perten, 1990). The gluten index method can be also used to determine SP damage in flour, since SP damaged wheat contains proteolytic enzymes which weaken the gluten bonds, resultings in an obvious decrease of the gluten index value (Aja *et al.*, 2004). Rheological parameters provide considerable preliminary information about the bread-making (Diraman *et al.*, 2013). Therefore, they are very important tests for cereal and milling industries. The farinograph measures the resistance of dough samples to mixing. It is used to evaluate absorption of flours and to determine stability and other characteristics of dough samples during mixing (AACCI, 2000). Farinograph dough development time is a good indicator of the protein quality of flour. Strong flours generally require longer dough development time than weak flours (Karababa and Ozan, 1998). The extensograph records a force-time curve for a test piece of dough stretched until it breaks. Characteristics of force-time curves, or extensograms, are used to assess the general quality of flour (AACCI, 2000).

As shown in the Table 1, the SW sample used in blends in order to improve the quality had a thousand kernel and hectolitre weight of 38.4 g and 79.4 kg, respectively (i.e. 'first grade' bread wheat [TS 2974; TSE, 2003]). The SW wheat sample had a semi hard, large size, and a homogeneous structure as well as good quality features in terms of technological and rheological characteristics (Table 2-5).

As expected, along with the increase of the SW portion in the blend, SP damaged kernel ratio decreased, and thousand kernel and hectolitre weight, and largeness values increased ($P<0.05$; Table 1 and 2). The increase of SW in the blends caused a clear and significant improvement in flour characteristics (Table 3). The blends had higher values in terms of gluten and amylase quantity compared to the SW sample. Gluten quantity and amylase activity increased with a larger percentage of SPDW in the blend ($P<0.05$). Falling number, sedimentation, and gluten index values of flour groups increased, therefore, gluten quality was improved, whereas wet and dry gluten content decreased along with a decrease of SPDW in the blend (Table 3). The increase in the ratio of SW in blends caused a limited increase of the sedimentation value, and a large increase of the delayed sedimentation and gluten index values ($P<0.05$). An increase in gluten index value is an indicator of the gluten quality (Perten, 1990), clearly seen at the low percentage (<70% SW) blends, and to a limited degree in the 30-70% blend. Like our previous study (Dizlek and Özer, 2016), the presence of SPDW in blends decreased the quality of the gluten. In this study, the effect of SP protease activity on sedimentation and gluten index was very clearly demonstrated. The results from farinograph and extensograph confirmed this effect. The quality of the flour (Table 3 and 4) and the dough (Table 5) already declined significantly at the 10-90% blend ($P<0.05$); the dough prepared with the 30-70% blend at ≥90 min was too deteriorated to be measured by the extensograph device.

Sedimentation tests (Zeleny and delayed Zeleny) were performed to determine to what extent the wheat was exposed to SP damage. Zeleny and delayed Zeleny sedimentation values decrease with an increase in the SPDW portion in blends (Dizlek and Islamoglu, 2015). Our results (Table 3) were consistent with the findings of Dizlek and Isamoglu (2015).

The data from our study showed that one needs to be very careful about the ratio of HLSPDW used in blending. A wheat sample that has a good-medium bread quality could be spoiled through blending. Particularly, the results obtained from the farinograph and extensograph (Table 4 and 5, respectively) show that flour and dough characteristics obtained from the 10-90% blend were significantly more reduced than the characteristics from SW. These reductions are about 16% in dough development time, about 29% in stability time, about 58% in – taken into consideration in the industry – 135 min maximum resistance to extension, and about 52% in 135 min energy values. In a similar manner, Diraman and Boyacioglu (1997) pointed out that addition of 40% SW (American HRW [hard, red, winter] wheat) to a wheat variety with a SP damage ratio of 10-12% (40% SW + 100% SPDW) could not improve the quality of the blend. The sedimentation and alveograf values of this blend were the most obvious indicators of SPDW in this situation.

It has been well documented that when the percentage of SP damaged kernels increases in wheat mass, bread-making quality characteristics of the wheat decrease (Dizlek and Özer, 2016; ICARDA, 1983; Karababa and Ozan, 1998). Similar results were obtained from the present blending study (Table 1-5), however, due to differences in quality of the wheat varieties and the ratio of SP damaged grain used in these studies, there was a variation between the level of changes occurring in wheat flour and dough quality.

Kocak *et al.* (1993) reported that considering flour yield of wheat varieties using in blending application, the difference between found the expected values in the blending and the actual values. Hook (1983) explained that these differences occur due to interaction between varieties. In this study, the same wheat variety (Sagittario) was used for blending to avoid interaction between varieties; therefore the theoretically calculated value and practically found value correlated substantially with each other.

Wheat flour is one of the most important components in bread-making not only for quantitative but also for qualitative purposes. In bread production, wheat flour has 3 basic functions: protein quantity and quality, amylase activity, and water absorption capacity. Among these functions, protein quantity and quality are critical in determining the functional characteristics of wheat flour. Among wheat proteins, gluten proteins (gliadin and glutenin) mainly determine baking quality of the wheat/flour (Dizlek and Özer, 2016; Dizlek *et al.*, 2006). In this study, we observed that when the SW sample ratio increased in the blend, the gluten quality of the flour samples increased very sharply, gluten quantity decreased within a limited range, amylase activity of flour samples decreased (falling number value increased) and water absorption capacity of flour samples changed within a limited range ($P<0.05$; Table 3 and 4).

Studies have shown that SP damage could be relatively reduced by mixing wheat damaged by SP with the hard, strong, and sound wheat at specific ratios (Atli *et al.*, 1988b; Diraman *et al.*, 1998; Ozkaya and Ozkaya, 1993; Unal *et al.*, 1993). In this study, similar results were obtained. Kocak and Atli (1996) carried out a research to improve the dough characteristics for suitable bread-making by blending bread wheat varieties having different qualities. They formed blending groups by adding low quality varieties to high quality ones at 20, 40, 60 and 80%. They reported that addition of the hard red varieties to low quality varieties increased the quality of flour/dough characteristics (decrease in softening degree; increase in dough development time, stability, resistance to extension, maximum resistance to extension, and energy). The results of the present study were consistent with that of Kocak and Atli (1996). When the SP ratio is higher than a certain level (varying on the quality of the wheat), the improvement of the baking qualities was impossible. However, when wheat has only a limited level of SP damage, it might be economically interesting to apply blending with SW (TAGEM, 2004).

For application of wheat blending, each wheat mass used for blending should be well characterised. In addition, it is useful to take factors, such as SP damaged grain ratio (%), classification SPDW kernels within itself according to their sucking degree (1/4, 2/4, 3/4 and 4/4), SP sucking number on a kernel (single, double, triple), and damaging circuit (stage) of SP to the wheat, into account. Incorrect blending could waste the use of good SW as well as the blend itself.

4. Conclusions

The aim of this study was to improve the quality characteristics of HLSPDW by blending. When SPDW was blended with SW, the harm of SP relatively decreased. As the SPDW portion in the blend increased, the physical, technological, and rheological characteristics of wheat declined ($P<0.05$). The HLSPDW used in the blend is more decisive than the SW in determination of the quality of the wheat, wheat flour, and dough. In addition, the ratio of the SPDW in the blending is dominant in specifying the quality of the first (wheat) and intermediate (flour and dough) products. The low quality wheat affects the high quality wheat more and deteriorates the product quality. In this study, even the 10-90% blend resembled the SPDW characteristics more than SW. Therefore, one should be very careful about the amount of HLSPDW mass used in blending. A wheat sample that has a good-medium bread quality could be spoiled through blending with SPDW. In this study, the optimal blending ratio was 10-90% by taking into account the other remaining criteria, except for the extensograph values; however, the application of blending was inadequate for the improvement of wheat quality exposed to a high level of the SP damage. This technique could be implemented in combination with some other methods, such as using additives in bread-making or the use of more superior, strong, hard wheat in blending process.

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