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Effects of sunn pest (*Eurygaster integriceps*) damage ratio on physical, chemical, and technological characteristics of wheat

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RESEARCH ARTICLE

Abstract

Sunn pest (SP) reduces both wheat yield and quality. Different researchers reported different sunn pest damage ratios (SPDR) in the range of 0.3 to 10%, which can lead to confusion on the determination of the level of destroying the technological quality of wheat. The aim of this study was to determine the effects of SPDR on two bread wheat quality. In the study, Golia and Sagittario wheat varieties with SPDR of 3.92 and 7.8% were used, respectively. Selection of SP damaged kernels in each variety was made manually. Experimental samples were prepared by separating damaged kernels from wheat bulk and then by mixing sound kernels at different ratios of 2, 4, 8, 12, 16, and 100%. These damaged samples were compared with undamaged sample (0% = control). Main physical, chemical, and technological characteristics of two variety wheat groups were determined. It was observed that SPDR in wheat bulk plays an important role in quality characteristics of wheat varieties. The increase in SPDR in wheat bulk caused a decrease on physical and technological characteristics. SPDR significantly affected thousands of kernels and hectolitre weight of wheat varieties. Crude fibre and ash contents of samples increased sharply; crude protein, dry gluten, and starch contents decreased partially; falling number, delayed zeleny sedimentation test, and delayed gluten index values decreased accurately depending on increasing level of SPDR in wheat bulk. It was found that the decrease in quality characteristics started with 2% SPDR and wheat-flour properties reduced significantly after 4% in both wheat varieties.

Keywords: physical characteristic, sunn pest, sunn pest damage ratio, technological characteristic, wheat quality

1. Introduction

Wheat is grown in 218,460,701 ha throughout the world, and also 713,182,914 tons of grains were produced in 2013. Wheat, takes the first place in field crops in Turkey with the 7,772,600 ha growing area and 22,050,000 ton annual production, takes the first place in field crops in Turkey (http://faostat3.fao.org). It retains its features of having the feedstock of human beings basic nutrients. Especially from North Africa to Central Asia, it accounts for half of the total dietary calories (Reynolds *et al.*, 2008).

Physicochemical (technological) features of wheat were affected dramatically by cultivar genetic properties, weather conditions, soil features, fertilising and agronomical applications, cereal diseases and harmful insects in both vegetative and storage periods (Altenbach *et al.*, 2002; Köksel and Sivri, 2002; Torbica *et al.*, 2007). Wheat is damaged by bugs, and that damage has produced important economic losses to millers and bakers (Lorenz and Meredith, 1988a). These bugs reduce both wheat yield and quality (Dıraman *et al.*, 2013). The unique characteristic of bug-damaged wheat is a disrupted protein structure due to the action of some injected proteinases (Kretovich, 1944). Bug-damaged wheat causes reduced 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).

In Eastern Europe, the Middle East, and North Africa, pre-harvest wheat damage has been attributed to two genera of heteropterous, *Aelia spp.* and *Eurygaster spp.*, and in

New Zealand, *Nysius huttoni* is considered responsible for the wheat damage (Cressey *et al.*, 1987; Rosell *et al.*, 2002a). In Turkey, bug-damage of wheat is considered as an endemic problem, which has been associated with the bug *Eurygaster integriceps* Put. (Hemiptera: Scutelleridae), sunn pest (SP). This species caused a serious damage particularly in the southern and south-eastern Anatolia (Karababa and Ozan, 1998; Lodos, 1982). In Turkey, thousands of dollars are spent annually for struggling with the SP. In 2014, an area of 636.281 ha were made insect (SP) control (General Directorate of Food and Control, 2015). According to the calculations of the Turkish Ministry of Food, Agriculture and Livestock, in 2011, the national economy contributed about 370 million dollars to the fight against the SP in 22 provinces. However, farmers lost an amount of about 20 million dollars due to the SP damage cause allocated to coarse wheat (Union of Turkey Agriculture Chambers, 2014).

There have been various studies in the literature on the percentage of bug-damaged kernels in wheat necessary to seriously affect the product and baking quality. Different researchers reported very different sunn pest damage ratios (SPDR), which can lead to confusion on the determination of the level of destroying the technological quality of wheat. Meredith (1970) and Yakovenko *et al.* (1973) suggested 0.3-0.4% SPDR; Vasileva *et al.* (1996) suggested 1%; Tekeli (1964) and Lodos (1982) suggested 2%; El-Haramein *et al.* (1984) and Critchley (1998) *et al.* suggested 2-3%; Kosmin (1933) and Matsoukas and Morrison (1990) suggested 3%; Rumyantseva (1981), Köksel *et al.* (2002), and Sivri *et al.* (2004) suggested 3-5%; Josephides (1993), Karababa and Ozan (1998), Hariri *et al.* (2000), and Olanca *et al.* (2008) suggested 5%; Shurovenkov *et al.* (1984) suggested 7%. However, Cressey (1987) reported that wheat containing 10% bug-damaged kernels would not have been classified as bug-damaged. Every *et al.* (1989) showed that grist containing 1-10% damaged kernels by *Nysius huttoni* produced bread of reduced quality but was not classified as bug-damaged in New Zealand wheat's. Only grist containing of more than 10% damaged kernels produced bread that would have been classified as bug-damaged. These differences between the studies may be explained by the different insects (*Eurygaster*, *Aelia*, and *Nysius*) found to infest wheat cultivars, population density of the insect, weather conditions, water availability, duration of the crop growing period, occurring stage of insect damage, infection ratio of wheat by insect, and wheat cultivar characteristics (Dizlek and İslamoğlu, 2009, 2015; Dizlek *et al.*, 2008a; Karababa and Ozan, 1998). In this subject, it has been well documented that when the percentage of damaged kernels increases in wheat mass, quality characteristics of wheat decrease (ICARDA, 1983; Karababa and Ozan, 1998).

The aim of this study was to determine the effects of *Eurygaster integriceps* damage ratio on bread wheat quality (parameters especially related to protein in order to predict maximum allowable amount of damaged kernels in the wheat varieties). For this purpose, kernels that damaged by SP were removed (cleaned) from Golia and Sagittario wheat varieties and following new groups were created by mixing them with undamaged kernels at different levels (0, 2, 4, 8, 12, 16, and 100%). It was aimed to investigate the effects of the different SPDR in wheat bulk on basic qualifications of wheat (physical, chemical, and technological).

2. Materials and methods

Materials

In this study, insect-damaged two bread wheat varieties, Golia and Sagittario purchased from Devecioğulları and Demir Trading Companies, (Nurdağı, Gaziantep, Turkey), respectively, were used. For the determination of the ratio of insect damaged kernel of two wheat varieties, 10 sets of 100 kernels were separated randomly from the each wheat cultivars. The number of SP damaged kernels in each set was recorded and per cent damage ratio was reported as the average of ten determinations (Atli *et al.*, 1988a). In the result, Golia and Sagittario varieties had SPDR as 3.92 and 7.8%, respectively. Then, experimental materials were prepared as follows: SP damaged and sound kernels were separated manually from each wheat variety (by three scientists from Agricultural Protection Research Institute (Adana, Turkey) specialised in identification of insect damaged kernels). This procedure was repeated numerously to obtain sufficient amount of samples of each wheat varieties to complete research. The damaged wheat kernels were separated and added back to the undamaged kernels in different proportions: 0, 2, 4, 8, 12, 16, and 100%. Each wheat groups were mixed thoroughly for making homogeneous. Thus, in every wheat variety seven different wheat groups including kernels with control (without SP damage), 2, 4, 8, 12, 16, and 100% were formed. Great care was given in choosing almost the same sized damaged kernels to form groups, whereas the weak and broken kernels were eliminated. These materials were used in physical and chemical analyses of wheat samples.

Methods

Prepared blended wheat samples which had different SPDR were conditioned to 16.5% moisture content for 32 h and were milled with a laboratory type mill ('Yücebaş' brand, 'YM1' model tempered wheat grinding mill, including four rolls; Yücebaş Machine, İzmir, Turkey) separately. After that, obtained flour samples were sifted in order not to keep the ash content of flour very high. These flour samples were used for chemical, particle size distribution, and technological analyses. In chemical analyses of wheat samples (including two varieties and seven groups) a hammer mill (Yücebaş Machine, İzmir, Turkey) was used to produce whole grain wheat flour.

Measurements of physical, chemical, and technological properties of wheat groups

Main physical, chemical, and technological analyses were determined for the blended healthy and SP damaged wheat kernels. According to Uluöz (1965) thousand kernel weight (TKW), hectolitre weight (HW), 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 cleaning the foreign matters, the 100 g of wheat sample was sifted through sieves with size of 2.8, 2.5 and 2.2 mm, respectively. Then, the amounts of wheat on each sieve were weighed, and the rates were determined. The wheat samples with consecutive on-sieve rates of +75% were considered as homogenous (Elgün *et al.*, 2002).

Particle size distribution of wheat flour groups was also determined according to Uluöz (1965). For this purpose sieve kit (type 70, mesh number 100493; Bühler-MIAG GmbH, Braunschweig, Germany) was used. Moisture, ash, crude protein (CP), starch, and crude fibre content (CFC) of wheat and wheat flour groups were determined according to American Association of Cereal Chemists International (AACCI) approved methods No. 44-19.01, 08-01.01, 46-09.01, 76-11.01, 32-10.01 (AACCI, 2000), respectively.

Wheat flour groups were objected to zeleny sedimentation test (ZST; AACCI method 56-60.01; AACCI, 2000), delayed zeleny sedimentation test (DZST; Greenaway *et al.*, 1965), wet gluten content (WGC) and dry gluten content (DGC; AACCI method 38-10.01; AACCI, 2000), gluten index value (GIV; AACCI method 38-12.02; AACCI, 2000), delayed gluten index value (DGIV; Aja *et al.*, 2004), and falling number value (FNV; AACCI method 56-81.03; AACCI, 2000) in order to determine some important technological characteristics. The flour samples were incubated for 2 h at 30 °C in the ZST tube after addition of the brome phenol blue solution for allowing proteolytic reactions to occur in DZST. Standard time (0 min) in GIV was extended to 120 min in DGIV (wet gluten (WG) samples were put in gluten index (GI) machine after the 2 h resting for the determination of DGIV). In addition, structures of WG after the resting 2 h in all wheat flour groups were determined by subjective evaluations (Dıraman and Atli, 2005).

In the study, damaged groups (2, 4, 8, 12, 16, and 100%) were compared with undamaged group (0% = control). All analytical results were corrected to 14% moisture basis.

Statistical analysis

Analyses were carried out in three replicates. Analyses of variance (ANOVA) were conducted by using the SAS procedures (v6.12 for Windows; SAS, Cary, NC, USA). When a significant difference was found among treatments, Duncan's multiple range tests were performed to determine the differences among the mean values ($P<0.05$).

3. Results and discussion

The effects of different SPDR on the TKW and HW are given in Table 1. According to the results, SPDR significantly affected TKW and HW of wheat varieties significantly ($P<0.05$). It was determined that an increase in SPDR in wheat bulk caused a clear and significant decrease in the TKW and HW values of the varieties. This situation shows clearly that when SP gives harm to wheat, SP nymphs suck the sap of grains, the digestive secretions injected into the grains, they feed on gluten (storage protein) and starch (storage carbohydrate) and it leads to reduction in grain weight (Atli *et al.*, 1988a,b; Rashwani, 1984).

TKW and HW are important quality characteristics for determining the suitability of wheat for milling (Karababa and Ozan, 1998). TKW is positively correlated with flour

Table 1. Effects of sunn pest damage ratio (SPDR) on the thousand kernel weight and hectolitre weight values of the wheat varieties.[1]

SPDR (%)	Thousand kernel weight (g)[2]		Hectolitre weight (kg)	
	Golia	Sagittario	Golia	Sagittario
0 (control)	21.1^{a}	37.0^{a}	76.1^{a}	81.1^{a}
2	20.9^{b}	36.9^{a}	75.6^{b}	80.9^{b}
4	20.5^{c}	36.6^{b}	74.6^{c}	80.6^{c}
8	20.2^{d}	36.2^{c}	72.9^{d}	80.2^{d}
12	19.7^{e}	35.8^{d}	71.6^{e}	79.5^{e}
16	19.3^{f}	35.3^{e}	70.3^{f}	77.9^{f}
100	16.8^{g}	27.6^{f}	64.3^{g}	67.5^{g}

[1] Mean values in the same column followed by different superscript letters are significantly different ($P<0.05$).
[2] Calculation based on dry matter basis.

yield (Lee *et al.*, 1983). Soundness of the grain also directly influences flour quality and yield. According to Critchley (1998), the TKW of SP damaged wheat can be 8-22% lower than that of the undamaged kernel. Hariri *et al.* (2000) detected that the average reduction in TKW due to SP damage was about 24% in bread wheat and 20% in durum wheat varieties. In this study, SP damage resulted in decreases in TKW till 20.4% for Golia and 25.4% for Sagittario, and HW till 15.5% for Golia and 16.8% for Sagittario compared to undamaged control sample (Table 1). The difference between control and 16% bug-damaged group was approximately 2 g for kernel weight. There are nearly 4 g difference in Golia and 10 g difference in Sagittario between control and 100% bug-damaged group in terms of grain weight.

Vitreousness is an important property in the grading of wheat (Bushuk, 1998). Wheat endosperm varies both in texture (hardness) and appearance (vitreousness). Traditionally, vitreousness has been associated with hardness and high protein content and opacity (mealiness) with softness and low protein (Hoseney, 1994). In every two wheat varieties, vitreous kernel content relatively decreased, and therefore mealy (floury) kernel content increased ($P<0.05$) by the increase at a ratio of SP infected kernels in wheat bulk (Table 2). It was observed that when the SPDR in wheat bulk was increased, wheat samples were shown to get soft kernel characteristics. No evident difference was found between all the wheat groups except for 100% SPDR group in terms of translucent (semi vitreous) kernel content.

When the level of SPDR in wheat bulk was over 4% in the Golia variety, the largeness of bulk declined, and under size (≤2.2 mm) wheat mass ratio has increased significantly ($P<0.05$; Table 3). It was found that SPDR in wheat bulk had a limited effect on kernel size of Sagittario. As a result of visual inspection of SP damaged grains, these kernels were similar in terms of size with the observed undamaged sound kernels. This indicates that the occurrence of SP damage in the Sagittario variety may have coincided with the waxy-ripe stage of wheat (Atli *et al.*, 1988a; Lorenz and Meredith, 1988b). It was determined that SPDR was more effective on kernel size value of the Golia variety, whereas the Sagittario variety was affected at a limited range.

When the obtained data were evaluated together (Table 1-3), in general, the increase in SPDR in wheat bulk resulted in a decrease on physical characteristics ($P<0.05$) because of the endosperm content of the kernels bitten by SP. In terms of TKW, HW, and vitreousness properties, similar results were found for both Sagittario and Golia varieties (Table 1 and 2). As expected, the control sample had higher results than the bug-damaged samples for all tested physical quality parameters. Our findings on the physical properties of wheat were consistent with the findings in the literature (Critchley, 1998; Dizlek and İslamoğlu, 2009; Hariri *et al.*, 2000; Karababa and Ozan, 1998; Kinaci and Kinaci, 2004; Rashwani and Cardona, 1984).

The effects of SPDR on the particle sizes of wheat flour varieties are given in Table 4. It was found that the increase in SPDR in Golia and Sagittario wheat bulks caused a significant ($P<0.05$) decrease in the amount of flour samples which had particle sizes between 0-150 μm (particle size of flour increased). The results obtained for both wheat flours were in good accordance with each other.

The effects of SPDR on the chemical compositions of the wheat and flour varieties are given in Table 5. Within a variety, no significant difference ($P>0.05$) was found between different SPDR groups in terms of moisture content. Wheat samples must contain less than 14% amount of moisture in order to be safely store (Kent, 1982). In this study, wheat groups did not exceed the critical moisture level of 14%. When the SPDR in wheat bulk were increased, ash content and CFC of wheat were increased in both wheat varieties ($P<0.05$), but the rate of increase depends on the variety.

Table 2. Effects of sunn pest damage ratio (SPDR) on the vitreousness and mealiness of the wheat varieties.[1]

SPDR (%)	Vitreous		Translucent		Mealy	
	Golia	Sagittario	Golia	Sagittario	Golia	Sagittario
0 (control)	22.0^{ab}	18.7^{a}	74.7^{a}	76.7^{c}	3.3^{e}	4.6^{d}
2	23.1^{ab}	18.1^{a}	73.9^{ab}	76.5^{c}	3.0^{e}	5.4^{d}
4	24.6^{a}	15.5^{b}	72.3^{b}	79.7^{b}	3.1^{e}	4.8^{d}
8	21.1^{b}	11.6^{c}	74.4^{a}	85.4^{a}	4.5^{d}	3.0^{d}
12	19.7^{c}	10.8^{cd}	74.6^{a}	80.3^{ab}	5.7^{c}	8.9^{c}
16	18.1^{d}	10.1^{d}	74.8^{a}	78.9^{b}	7.1^{b}	11.0^{b}
100	12.0^{e}	6.7^{e}	64.0^{c}	67.3^{d}	24.0^{a}	26.0^{a}

[1] Mean values in the same column followed by different superscript letters are significantly different ($P<0.05$).

Table 3. Kernel size distribution values of wheat groups having different sunn pest damage ratio (SPDR).[1]

SPDR (%)	Large (≥2.8 mm)	Medium (2.5-2.8 mm)	Small (2.2-2.5 mm)	Undersize (≤2.2 mm)	Largeness-homogeneity
Golia					
0 (control)	13.7^{ab}	28.5^{a}	31.1^{b}	26.7^{d}	small-heterogeneous
2	14.0^{ab}	28.6^{a}	31.2^{b}	26.2^{d}	small-heterogeneous
4	14.6^{a}	28.4^{a}	31.5^{b}	25.5^{d}	small-heterogeneous
8	13.6^{ab}	27.1^{b}	29.9^{c}	29.4^{c}	small-heterogeneous
12	13.1^{b}	26.1^{c}	30.4^{bc}	30.4^{b}	small-heterogeneous
16	12.7^{c}	25.4^{d}	30.7^{bc}	31.2^{a}	small-heterogeneous
100	11.3^{d}	23.3^{e}	34.0^{a}	31.4^{a}	small-heterogeneous
Sagittario					
0 (control)	44.6^{a}	35.4^{a}	15.7^{a}	4.3^{b}	large-homogeneous
2	43.9^{a}	35.1^{a}	15.9^{a}	5.1^{ab}	large-homogeneous
4	43.8^{a}	35.8^{a}	16.1^{a}	4.3^{b}	large-homogeneous
8	42.5^{a}	36.4^{a}	17.1^{a}	4.0^{b}	large-homogeneous
12	42.7^{a}	35.9^{a}	16.4^{a}	5.0^{ab}	large-homogeneous
16	42.1^{a}	35.8^{a}	16.4^{a}	5.7^{a}	large-homogeneous
100	44.5^{a}	35.8^{a}	15.8^{a}	3.9^{b}	large-homogeneous

[1] Mean values in the same column within a wheat variety followed by different superscript letters are significantly different ($P<0.05$).

Table 4. Effects of sunn pest damage ratio (SPDR) on the particle sizes of wheat flour varieties.[1]

SPDR (%)	Screen openings			
	≥425 µm	265-425 µm	150-265 µm	0-150 µm
Golia				
0 (control)	0.3^{b}	6.2^{b}	38.9^{c}	54.6^{a}
2	0.3^{b}	6.6^{b}	39.9^{c}	53.0^{a}
4	0.3^{b}	6.6^{b}	39.2^{c}	53.9^{a}
8	0.4^{b}	6.5^{b}	41.2^{c}	47.5^{b}
12	0.3^{b}	6.7^{b}	46.5^{b}	41.1^{c}
16	0.5^{b}	6.7^{b}	45.7^{b}	39.8^{c}
100	1.5^{a}	8.0^{a}	71.2^{a}	19.3^{d}
Sagittario				
0 (control)	0.2^{b}	4.0^{b}	37.0^{b}	58.8^{a}
2	0.4^{b}	4.0^{b}	35.5^{c}	55.3^{a}
4	0.3^{b}	4.2^{b}	38.9^{c}	54.9^{a}
8	0.3^{b}	4.5^{b}	37.3^{c}	57.9^{a}
12	0.4^{b}	4.8^{b}	44.5^{b}	51.1^{b}
16	0.3^{b}	4.7^{b}	46.1^{b}	44.3^{c}
100	1.4^{a}	7.1^{a}	69.9^{a}	21.6^{d}

[1] Mean values in the same column and same variety (Golia or Sagittario) followed by different superscript letters are significantly different ($P<0.05$).

As expected, the increase in SPDR in wheat bulk caused a decrease in CP and starch content of wheat (Rashwani, 1984; Waage, 1998). In respect thereof, all sucking insects pierce the seed coat and inject saliva to solubilise the nutrients. The salivary secretions contain amylolytic and proteolytic enzymes that persist in the grain after feeding. Insects which feed on immature wheat grains, by attacking the developing kernels and sucking the cell content to derive their food (Köksel *et al.*, 2002).

Table 5. Effects of sunn pest damage ratio (SPDR) on the chemical compositions of the wheat and wheat flour varieties.[1]

SPDR (%)	Moisture	Ash[2]	Crude protein[2]	Starch[2]	Crude fibre[2]
Golia wheat					
0 (control)	10.41[a]	2.17[c]	16.0[a]	62.7[a]	2.71[f]
2	10.41[a]	2.16[c]	16.0[a]	62.5[a]	3.07[e]
4	10.43[a]	2.15[c]	16.1[a]	62.2[b]	3.85[d]
8	10.44[a]	2.19[bc]	16.0[a]	62.2[b]	3.94[cd]
12	10.40[a]	2.21[b]	15.9[a]	62.1[bc]	4.01[c]
16	10.42[a]	2.23[b]	15.8[a]	61.9[c]	4.12[b]
100	10.40[a]	2.32[a]	14.9[b]	61.2[d]	4.83[a]
Sagittario wheat					
0 (control)	12.24[a]	1.57[c]	17.8[a]	71.5[a]	2.41[e]
2	12.25[a]	1.58[c]	17.7[a]	71.5[a]	2.46[de]
4	12.28[a]	1.61[bc]	17.2[ab]	71.2[b]	2.51[d]
8	12.35[a]	1.62[bc]	16.4[b]	0.8[c]	2.63[c]
12	12.24[a]	1.64[b]	16.5[b]	70.6[c]	2.66[bc]
16	12.22[a]	1.65[b]	16.5[b]	70.5[c]	2.73[b]
100	12.19[a]	1.78[a]	16.0[c]	69.9[d]	2.98[a]
Golia wheat flour					
0 (control)	15.36[a]	0.69[a]	15.1[a]	78.0[a]	0.95[e]
2	15.25[a]	0.68[a]	15.0[a]	77.7[a]	1.12[d]
4	15.08[a]	0.68[a]	15.3[a]	76.6[b]	1.65[c]
8	15.11[a]	0.69[a]	14.9[a]	76.9[b]	1.59[c]
12	14.98[a]	0.69[a]	14.9[a]	76.2[c]	1.69[bc]
16	15.01[a]	0.68[a]	14.4[b]	76.0[c]	1.77[b]
100	13.63[b]	0.70[a]	12.2[c]	75.6[d]	2.08[a]
Sagittario wheat flour					
0 (control)	14.80[a]	0.56[a]	16.1[a]	79.6[a]	0.76[c]
2	14.61[a]	0.53[a]	16.1[a]	79.5[a]	0.78[c]
4	14.63[a]	0.55[a]	16.0[a]	79.5[a]	0.80[c]
8	14.47[a]	0.54[a]	15.9[ab]	79.6[a]	0.77[c]
12	14.48[a]	0.54[a]	15.7[b]	79.4[a]	0.82[c]
16	14.35[a]	0.55[a]	15.4[c]	79.3[a]	0.90[b]
100	13.42[b]	0.56[a]	14.4[d]	78.8[b]	1.14[a]

[1] Mean values in the same column and same wheat or wheat flour varieties (Golia or Sagittario) followed by different superscript letters are significantly different ($P<0.05$).
[2] Calculation based on the dry matter basis.

SP feed grains at different stages of development (Ravan *et al.*, 2009). CFC and ash content of Golia groups were higher than Sagittario groups, because SP damage occurs in Golia group at earlier stage and so grains have relatively puny structure. Köksel *et al.* (2002) and Özberk *et al.* (2005) reported that during the early stages of kernel development, for example, milk ripe stage, most of the kernel contents can be sucked out by the SP, resulted in smaller, lighter and shrivelled kernels.

In both wheat flour varieties no statistical significant effect ($P>0.05$) was found between control and 2-16% SPDR groups in terms of moisture content. However, moisture content of the flour samples with 100% SPDR wheat groups was significantly ($P<0.05$) lower than the other samples (Table 5). This may be resulted from SP damage which provides drier, tougher, and shrivelled structure to outer layers of wheat.

As can be seen in Table 5, SPDR affected the ash content of wheat's significantly whereas it did not affect the ash content of flour samples. Increase in SPDR in wheat bulk caused a decrease in crude protein content (CPC) of wheat flour groups produced from wheat having different SPDR. CPC of flour obtained especially from wheat mass of 100% SPDR is significantly lower, independent from wheat variety, than that of other groups classified according to SPDR. CPC of flour obtained from wheat mass with lower SPDR (up to 8%) had no prominent change compared to flour obtained from undamaged wheat (Table 5). CPC starts to decrease prominently (P<0.05) with 12% SPDR. The most significant decrease in CPC occurred in wheat mass with 100% SPDR for both Golia and Sagittario varieties. Although CPC of wheat mass with relatively lower SPDR did not change, its protein quality decreased compared to undamaged wheat mass (Table 6 and 7). In addition, the decline in CPC comes up in wheat mass with higher SPDR (12% and above). This finding was consistent with the findings of the many other conducted studies by researchers (Atli *et al.*, 1988a,b; Dıraman, 2009; Every *et al.*, 1990; Greenaway *et al.*, 1965; Lorenz and Meredith, 1988a,b; Perez *et al.*, 2005; Redman, 1971; Rosell *et al.*, 2002b) who reported damage of SP and other insects having the same effect with SP, affected the cereals protein quality rather than its protein content. Kinaci and Kinaci (2004) showed that the damage caused

Table 6. Effects of sunn pest damage ratio (SPDR) on the wet gluten content, dry gluten content, and falling number value of the wheat flour varieties.[1]

SPDR (%)	Wet gluten content (%)		Dry gluten content (%)		Falling number value (s)	
	Golia	Sagittario	Golia	Sagittario	Golia	Sagittario
0 (control)	28.7^{a}	29.7^{a}	9.8^{a}	10.00^{ab}	456^{a}	412^{a}
2	28.4^{a}	30.6^{a}	9.4^{b}	10.36^{a}	406^{b}	388^{b}
4	27.9^{a}	30.8^{a}	9.3^{b}	10.06^{ab}	404^{b}	77^{c}
8	28.0^{a}	29.9^{a}	9.1^{c}	10.00^{ab}	391^{c}	374^{d}
12	28.3^{a}	29.6^{a}	8.9^{d}	9.95^{b}	387^{d}	361^{e}
16	28.5^{a}	29.8^{a}	8.9^{d}	9.95^{b}	378^{e}	353^{f}
100	could not be washed		–	–	285^{f}	294^{g}

[1] Mean values in the same column followed by different superscript letters are significantly different (P<0.05).

Table 7. Effects of sunn pest damage ratio (SPDR) on the Zeleny sedimentation and delayed Zeleny sedimentation tests, gluten index and delayed gluten index values of the wheat flour varieties.[1]

SPDR (%)	Zeleny sedimentation test[2] (ml)	Delayed Zeleny sedimentation test[2,3] (ml)	Gluten index value (%)	Delayed gluten index value[3] (%)	Structure of gluten after the delaying (resting)
Golia					
0 (control)	30.6^{a}	37.7^{a}	100^{a}	96^{a}	not splay, spherical like ball
2	30.8^{a}	24.9^{b}	99^{a}	56^{b}	not splay, spherical like ball
4	29.4^{b}	11.3^{c}	99^{a}	22^{c}	little splay, slightly spherical like ball
8	25.5^{c}	8.7^{d}	71^{b}	0^{d}	very splay, very soft
12	25.0^{c}	6.6^{e}	59^{c}	0^{d}	very splay, very soft
16	23.5^{d}	5.6^{f}	30^{d}	0^{d}	extreme splay
100	9.1^{e}	3.0^{g}	0^{e}	0^{d}	
Sagittario					
0 (control)	28.3^{a}	28.3^{a}	97^{a}	89^{a}	little splay, spherical like ball
2	27.3^{a}	22.3^{b}	94^{ab}	39^{b}	little splay, slightly spherical like ball
4	27.3^{a}	17.2^{c}	88^{b}	5^{c}	Splay, soft
8	27.8^{a}	7.1^{d}	70^{c}	0^{d}	very splay, very soft
12	23.3^{b}	6.6^{e}	55^{d}	0^{d}	extreme splay
16	21.8^{c}	5.6^{f}	40^{e}	0^{d}	extreme splay
100	21.1^{d}	3.0^{g}	0^{f}	0^{d}	–

[1] Mean values in the same column and same variety (Golia or Sagittario) followed by different superscript letters are significantly different (P<0.05).
[2] Adjusted to 14% moisture basis.
[3] For the determination of effects of SP protease clearly delaying 2 h.

by SP pierced grain affects the TKW, CPC, and ZST value depending on the variety and grain type.

In each wheat variety, starch content of the flour groups was changed within a limited range (Table 5). The increase in SPDR in wheat bulk caused a decrease in starch content of flour samples in Golia variety. No significant difference (P>0.05) was found between all the Sagittario flour groups except for 100% SPDR group in terms of starch content.

There was a significant (P<0.05) difference detected between CFC of flour groups (Table 5). Accordingly, when the SPDR in wheat bulk was increased, CFC of wheat flour samples was shown to increase very evidently in both of two varieties. The main factors that cause this status, when the SP damage occurs wheat grains, it disrupts endosperm part of kernel by salivary enzyme secretions and sucking the grain content so that the outer layer (bran)/inner layer (endosperm) ratio in kernel is thought to be increased the outer layer.

The effects of different SPDR on the WGC, DGC, and FNV are given in Table 6. It was determined that SPDR in wheat bulk had no significant (P>0.05) effect on WGC of two varieties (Table 6). WG of varieties could not be washed from the 100% SPDR groups due to the intensive proteolytic enzyme activity. It was found that DGC values of Golia variety were decreased depending on increasing level of SPDR. It was observed that there was about 10% difference between control group of Golia, and group containing 16% level of SP damaged kernels in terms of the DGC. In contrast to Golia variety, it was determined that SPDR in wheat bulk had a limited effect on DGC of Sagittario groups. With the evaluation of FNV, it was found that amylase activities increased depending on increasing level of SPDR in wheat bulk (P<0.05). This case pointed out that there was amylase in SP secretion was compatible with findings of some early researchers (Atasanova and Popova, 1968; Dizlek *et al.*, 2008b; Kretovich, 1944; Lorenz and Meredith, 1988a).

The effects of different SPDR on the ZST, DZST, GIV, and DGIV are given in Table 7. Structural conditions after 2 h of WG samples produced from Golia wheat that has different damaged levels are given in Figure 1. ZST, DZST, WGC, DGC, and GIV were carried out for the determination of the effect of SP sucking number damage on the technological characteristics of wheat flour samples. In these analyses especially DZST, as improved by Greenaway *et al.* (1965), is used for the detection of SP damage in wheat flour (Dıraman, 2010; Dizlek and İslamoğlu, 2015).

Sedimentation tests (ZST and DZST) were performed to determine whether the wheat was exposed to SP damage, or to what extent it was. ZST and DZST values were determined to decrease when the SPDR increase in wheat varieties as expected. It was reported that how much the value in DZST is lower than the value in ZST means more SP damage (Elgün *et al.*, 2002; Özkaya and Özkaya, 2005). In this study, the results were consistent with the explanation above (Table 7).

Examining the DZST, in Golia and Sagittario varieties, it was determined that the effects of SP sucking ratios on the DZST values were significant (P<0.05). As ZST and DZST values are considered together (Table 7), it was observed that gluten quality in control samples was improved. The reason is that control samples include no SP damaged kernels; therefore, temperature (30 °C), at which flour slurry (flour + solution of brome phenol blue) are kept in DZST, increase the strength of gluten network structure (Dıraman and Atli, 2005; Dizlek and İslamoğlu, 2015).

The GIV is defined as the percentage of WG remaining on the sieve after automatic washing in a salt solution and centrifugation; it is a fast method to analyse gluten characteristics, indicating whether the gluten is weak, normal or strong (Perten, 1990). The GI method can be also used to determine SP damage in flour, since SP damaged wheat is composed of proteolytic enzymes which weaken the gluten bonds. This results in a significant decrease of the GIV (Aja *et al.*, 2004). As can be seen in Table 7, increase in SPDR in wheat bulk caused a decrease in GIV and DGIV

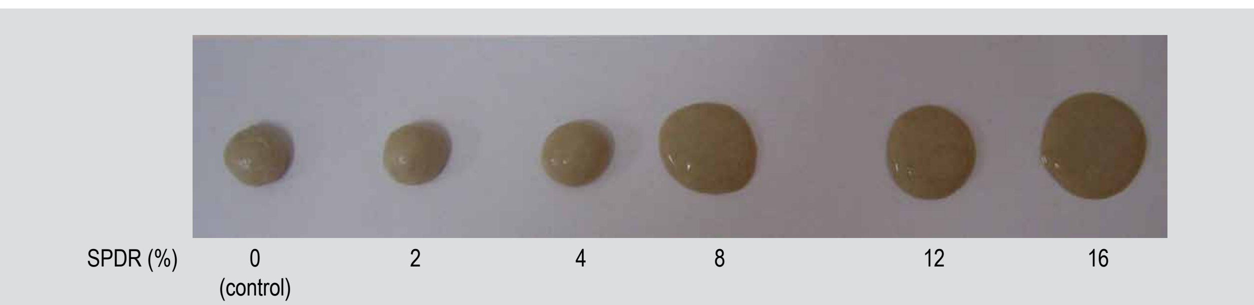

Figure 1. Gluten samples washed from Golia wheat flour, which have different sunn pest damage ratio (SPDR) just before delayed gluten index analysis.

of both of two wheat flour varieties. DGIV of varieties was decreased more sharply than GIV.

It was observed that particularly DZST and DGIV were affected obviously and significantly ($P<0.05$) by the level of SPDR in wheat bulk. At the level of 4% SPDR, there was a significantly decrease in gluten quality. However, when the level of SPDR was over 4%, it was determined that there was a significant decline in protein quality of flour samples. The critical level of SPDR was determined as 4% for Golia. When this ratio was over, a significant decline on flour quality was observed. DZST and DGIV give more accurate results than ZST and GIV in the determination of quality of SP damaged wheat and its flour (Dıraman, 2010). By the evaluation of DZST and DGIV (Table 7), it was observed that both wheat varieties examined in the study have quality loss and become significant after 2% SPDR value. As a result, it is thought that considering critical threshold value of 2% SPDR will be more convenient.

In subjective evaluation made just before delayed gluten index analyse, it was observed that the form of gluten was spherical like a ball in control sample and 2% damaged bulk (Table 7). Gluten had a splay and soft form with increasing of SPDR. It was determined that when the SPDR was 16%, gluten had very excessive splay and adhesive character (Figure 1).

With the evaluation of findings that belong to gluten quality values given in Table 7, it was determined that SPDR had significant ($P<0.05$) effect on wheat (flour) quality and one of the most important quality characteristic, gluten quality, was destroyed significantly when SPDR in wheat bulk was increased. It is thought that the fragmentation that occurred in the character of protein and starch by SP damage. With the evaluation of technological features that give information about bread quality (Table 6 and 7) it was determined that the bread quality of samples was affected by level of SPDR. It was observed that the flour-dough qualities and accordingly bread quality were destroyed seriously by increasing level of SPDR, and protein (gluten) quality was affected more than amount of protein by this deterioration. It was observed that flour-dough qualities weakened significantly depending on level of SPDR that caused to a degradation of protein structure. These results can be seen in Table 7, a clear decrease in DZST and DGIV, which can be attributed to the effect of enzyme which was injected to grains by SP (Every *et al.*, 1989; Kretovich, 1944).

It was observed that increasing level of SPDR only had desired effect on FNV of samples (due to increasing amylase activity of wheat according to flour depending on amylase secretion to kernel of SP because of insufficient amylase activity of wheat in making bread). Apart from this, it was determined that the increasing level of SPDR reduced significantly qualities of flour in all measurements. Depending on increasing level of SPDR, the information of that protein quality of flour samples was damaged more than amount of protein is compatible with information related to the subject presented before (Atli *et al.*, 1988a,b; Dıraman, 2009; Every *et al.*, 1990; Lorenz and Meredith, 1988a,b; Perez *et al.*, 2005; Rosell *et al.*, 2002b). As a result, it was observed that (Table 1-7) qualities of wheat and flour were shown a significant decline depending on the increasing level of SPDR kernels in both wheat varieties.

In bread production, wheat flour has three important functions: gluten quantity and quality, amylase activity, and water holding capacity. In this study, it was observed that when the SPDR in wheat bulk was increased, gluten quality of the flour samples was decreased very sharply, gluten quantity was changed within a limited range, and amylase activity of flour samples were increased (FNV was decreased) evidently (Table 6).

The results showed that wheat quality was negatively ($P<0.05$) and similarly affected by SP damage, however there was a variation derived from the genetically differences between varieties in terms of the flour qualities. Sagittario variety was determined to be affected excessively. Our findings were in accordance with the findings that belong to Cressey *et al.* (1987), Dıraman (2009), Dizlek and İslamoğlu (2009), Dizlek *et al.* (2008a), Every *et al.* (1998), Hariri *et al.* (2000), Karababa and Ozan (1998), Kinaci and Kinaci (2004), Kinaci *et al.* (1998), Kretovich (1944), Paulian and Popov (1980), Sivri *et al.* (1998, 2001, 2002). As expected, the control sample had higher results than the SP damaged samples for all physical and technological quality parameters (Table 1, 2, 3, 6, and 7).

Dizlek *et al.* (2008a) reported that each wheat variety was affected from SP damage differently and wheat varieties cannot be damaged by SP at the same degree. Karababa and Ozan (1998) reported that an allowable ratio of damaged kernels can be increased for high quality varieties.

It was determined that wheat technique worth criterions had been decreased by the increase in the percentage of SP infected kernels in wheat bulk. Increase in the ratio of infected kernels in wheat bulk did not have negative effects on wheat and flour quality at a certain proportion (2%). However, when the percentage of SP damaged kernels in wheat bulk was more than 2% and depending on increase of percentage, wheat and flour characteristics showed a significant ($P<0.05$) decrease.

4. Conclusions

The aim of this study was to determine the effects of SPDR on two bread wheat quality. The results of this study clearly demonstrated that the ratio of damage by SP in wheat bulk plays an important role in quality characteristics of wheat varieties. It was observed that the increase in SPDR in wheat bulk caused a clear and significant ($P<0.05$) decrease in physical and technological characteristics of the varieties. When the SPDR in wheat bulk was increased, ash content and CFC of wheat were increased, but starch content and CPC of wheat were decreased in both wheat varieties, but the rate of increase or decrease depends on variety. SPDR in wheat bulk, especially, affects DZST and DGIV of wheat varieties significantly ($P<0.05$), so not only DZST but also DGIV are good indicators in order to determine SP damage in wheat variety. It was found that a decrease in quality characteristics started from 2% SPDR and wheat-flour properties reduced significantly after 4% in both wheat varieties.

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