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EFFECTS OF SUNN PEST (*EURYGASTER* SPP.) SUCKING DEGREE IN GRAIN ON WHEAT QUALITY CHARACTERISTICS

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ABSTRACT

Sunn pest is the most important detrimental insect species for wheat in Turkey and neighbouring countries. Sunn pest reduce both wheat yield and quality. The aim of this study is to determine the effects of sunn pest sucking degree in wheat grain on two bread wheat (*Triticum aestivum* L.) quality. Experimental materials were formed by separating insect damaged wheat kernels into four categories as 1/4, 2/4, 3/4, and 4/4 according to their sucking degree. Main physical, chemical, biochemical, and technological characteristics of wheat groups were determined. Each wheat group had different quality characteristics and the increase in sucking degree (from 1/4 to 4/4) in sunn pest damaged wheat bulk caused to decrease on physical, biochemical, and technological characteristics. Golia variety was more sensitive than Sagittario in terms of sunn pest sucking degree. Protease and amylase activities, crude fibre and ash content of samples increased sharply; crude protein and starch content decreased partially; thousand kernels and hectolitre weight, largeness, falling number, and sedimentation values decreased accurately depending on increasing level of sucking degree in insect damaged wheat mass. Consequently; sucking degree in kernel had a strong effect on wheat quality characteristics and it is an important factor for evaluating insect damaged wheat mass properly. Therefore cereal industry should not only take damaged kernel ratio into consideration, but also sucking degree of insect damaged wheat mass must be considered. In classification of the sunn pest damaged grains, it should be, at least 1/4 and 2/4 sucked grains classified one group, 3/4 and 4/4 sucked grains classified another group. It would be also useful to give the proportion of these two groups in the insect damaged wheat mass.

Key words: insect damaged wheat, kernel categorization, sucking degree, sunn pest, wheat quality.

Abbreviations: AA: Amylase activity, AACCI: American Association of Cereal Chemists International, CFC: Crude fiber content, CPC: Crude protein content, DZST: Delayed Zeleny sedimentation test, DGC: Dry gluten content, FNV: Falling number value, GIV: Gluten index value, HW: Hectolitre weight, PA: Protease activity, SDS: sodium dodecyl sulfate, SP: Sunn pest, SPSD: Sunn pest sucking degree, TKW: Thousand kernels weight, WGC: Wet gluten content, ZST: Zeleny sedimentation test.

INTRODUCTION

Wheat technological properties are affected dramatically by cultivar genetic properties, weather conditions, soil features, fertilizing and agronomical applications, cereal diseases, and harmful insects in both vegetative and storage periods (Koksel and Sivri, 2002; Torbica et al., 2007). Wheat bug (Sunn pest [SP]; *Eurygaster* spp.), known in Turkey since 1927, is one of the most harmful pests of wheat in this region where the infested area has reached 636.281 ha and the cost of fight against the SP has reached 370 million USA dollars in 2011 (Dizlek and Islamoglu, 2015). The problem in Turkey has been associated with a bug, *Eurygaster integriceps* Put. SP (Hemiptera: Scutelleridae). This species caused big damage particularly in the southern and south-eastern Anatolia (Lodos, 1982; Karababa and Ozan, 1998). SP feeds grains at different stages of development (Ravan et al., 2009). Overwintered adults of the SP attack the leaves and stems of young, succulent wheat and barley plants causing them to wither and die prior to spike formation. It also feed at the base of the spike during the early growing period, resulting in greyish white spikes without kernels. Fourth and fifth nymph instars and new-generation adults of the SP feed on grains (Lodos, 1982).

Damage can range from complete destruction if the kernel is attacked in the 'milky' stage, to slightly shriveled if attacked in late maturity (Critchley, 1998). SP attacks

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after the milk stage of wheat causing shrivelling, reduced starch content, and lower grain weight (Waage, 1998). This result in direct damage to yield and viability of seeds and also this heavy infestation causes reduced crop yield, kernels and hectolitre weight (HW) decrease very sharply (Lorenz and Meredith, 1988a; Atli et al., 1988). If penetration occurs at a later stage of maturity, when the cell contents are fairly firm, the kernel surface is not deformed, but the opaque patch with its dark centre spot indicates that damage has occurred (Hariri et al., 2000), and in this situation wheat is affected less from SP compared to milk stage damage. So, wheat damage from SP, depends on the stage of growth of the insect as well as of the plants (Critchley, 1998). The endosperm in the damaged region is very soft and can be easily crumbled out, whereas in the undamaged part of the kernel it is normally hard. If the kernel has been pierced many times by the wheat bug it contains almost no endosperm (Kretovich, 1944). So, we can say that damaged kernels from wheat bug show very different properties to each other, also one should not put same category per SP damaged wheat grain (Dizlek et al., 2008a).

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, giving a softer dough and subsequently flat bread with low volume and unsatisfactory texture (Lorenz and Meredith, 1988a; Diraman et al., 2013). There are 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 bug-damage ratio (from 0.3% to 10%), which leads to confusion on this issue, for the level of destroying the technological quality of wheat (Yakovenko et al., 1973; El-Haramein et al., 1984; Every et al., 1989; Karababa and Ozan, 1998; Koksel et al., 2002; Dizlek and Ozer, 2016). 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, sucking degree (infection ratio) of wheat by insect and wheat cultivar characteristics (Karababa and Ozan, 1998; Dizlek and Islamoglu, 2009, 2015). In this subject, only one point is clear: When percentage of damaged kernels increases in wheat mass, quality parameters of wheat's were decrease (International Centre for Agricultural Research in the Dry Areas (ICARDA, 1983; Karababa and Ozan, 1998; Dizlek and Ozer, 2016).

Characterizing wheat masses correctly is possible by thoroughly evaluating the wheat kernels with SP sucking properly. However, different methods are used to determine the rate of sucked wheat kernels in Turkey. In the methods, only sucked kernel was considered, sucking number and sucking degree on the kernels were not regarded (Dizlek and Islamoglu, 2010, 2015). These cases have caused misleading results in evaluating the sucked kernels analysis. If the kernels are exposed to more SP damage, they have naturally more proteolysis activation and thus higher damage is observed to the quality of flour products (Kretovich, 1944; ICARDA, 1983; Lorenz and Meredith, 1988b; Koksel et al., 2002; Dizlek et al., 2008a).

In this study, we categorized the damaged wheat kernels which were separated manually into four categories according to their sucking degree (about 1/4 part of kernel was sucking, 2/4, 3/4, or 4/4 [all of kernel]). We investigated the effects of SP sucking degree (SPSD; 1/4, 2/4, 3/4, or 4/4) on the properties of two different wheat varieties. It was aimed to determine the effects of the different sucking degree in SP damaged grain on basic qualifications of wheat (physical, chemical, biochemical [enzymatic], and technological [physicochemical]).

MATERIAL AND METHODS

Materials

In this study, insect-damaged grains of two bread wheat cultivars (*Triticum aestivum* L.), Golia and Sagittario, purchased from Deveciogullari and Demir Trading Companies,

(Nurdagi, Gaziantep, Turkey) respectively were used. For the determination of the ratio of insect damaged kernel of the two wheat varieties, 10 sets of 100 kernels were separated randomly from each wheat variety. The number of SP damaged kernels in each set was recorded and percent damage ratio was reported as the average of ten determinations (Atli et al., 1988). In the result, Golia and Sagittario varieties had SP damage ratio 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 two scientists from Agricultural Protection Research Institute [Adana, Turkey] specialized in identification of insect damaged kernels). This procedure was repeated many times to obtain sufficient amount of samples of each wheat varieties necessary to complete research. Only SP damaged wheat kernels were used in this study. Insect damaged wheat kernels were separated into four categories as 1/4, 2/4, 3/4, or 4/4 infected kernels, according to their sucking degree (TAGEM, 1997, Figure 1 A and 1 B). So, four new wheat grain categories were formed according to their sucking degree. After, grains from each of the wheat groups were mixed thoroughly, so that the sample was homogeneous in itself. Thus, in every wheat variety, four different wheat groups including damaged kernels with 1/4, 2/4, 3/4, or 4/4 sucking degree were formed (Figure 1 C). Great care was taken in choosing almost the same sized (sucking degree) damaged kernels to form groups, whereas the broken kernels were eliminated ("Dokaj" process was applied.).

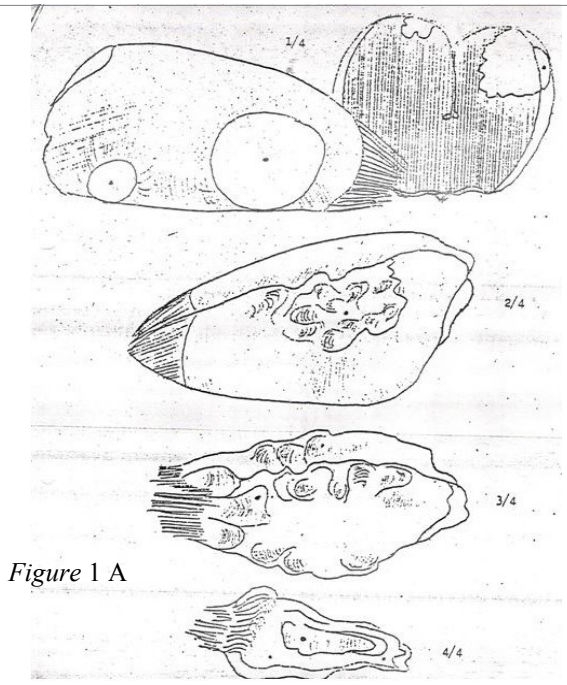

Figure 1 A

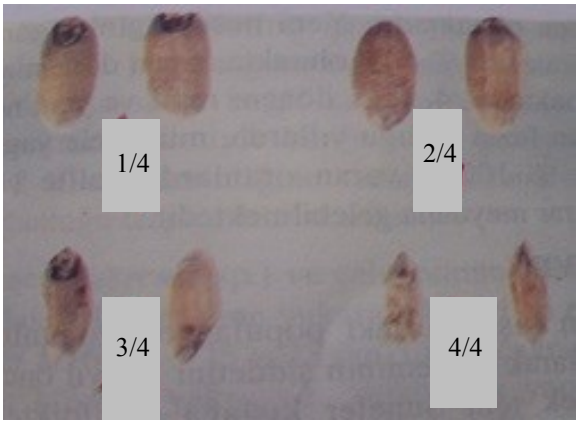

Figure 1 B

Figure 1 C

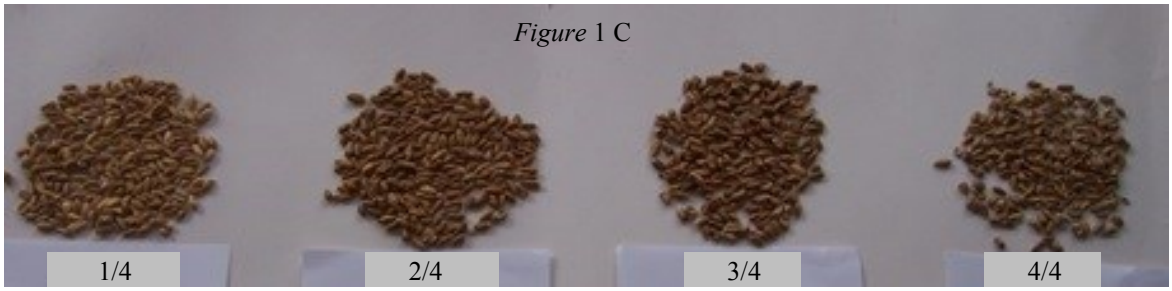

Figure 1. Sunn pest damaged wheat kernels separated into four categories according to their sucking degree (TAGEM, 1997, Figure 1 A and 1 B) and generated wheat groups in the study according to sunn pest sucking degree (1/4, 2/4, 3/4, and 4/4) on kernel (Figure 1 C)

Methods

In order to comprise the groups of wheat firstly, damaged and undamaged wheat by SP were chosen by using binocular (Koksel et al., 2002). Then, SP damaged kernels were grouped according to the damaging degrees as 1/4, 2/4, 3/4, or 4/4.

Prepared blended wheat samples which had different sucking degree were conditioned to 16% moisture content for 24 h and were milled with a laboratory type mill ("Yucebas" brand, "YM1" model tempered wheat grinding mill, including six rolls; Yucebas Machine, Izmir, 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 in chemical and technological analyses. In chemical and biochemical analyses of wheat samples (including two varieties and four groups) a hammer mill (Yucebas Machine, Izmir, Turkey) was used to produce whole grain wheat flour.

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

Main physical, chemical, biochemical, and technological characteristics of different SPSD in wheat kernels were determined. According to Uluoz (1965) thousand kernels weight (TKW) and HW of the wheat groups were determined. 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 (3 min) through sieves with size of 2.8 mm, 2.5 mm, 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. Moisture, ash, crude protein content (CPC), 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.

Proteolytic enzyme activity of wheat groups determined by the method Every (1991) with modification. Modification was performed by using spectrophotometric method instead of measuring the height of the gel. Amylolytic enzyme activity of wheat groups was determined according to AACCI Methods No 22-05.01 and 56-81.03 (AACCI, 2000).

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), and falling number value (FNV, AACCI Method 56-81.03; AACCI, 2000) in order to determine some important technological characteristics.

In the study, damaged groups (1/4, 2/4, 3/4, and 4/4) were compared with each other. 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 (The SAS System for Windows v6.12, 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 ($p<0.05$).

RESULTS AND DISCUSSION

Physical properties

The effects of different SPSD on the physical characteristics (TKW, HW, and largeness) of wheat were given at Table 1. The effects of the sucking degrees on the TKW and HW were found significant ($p<0.05$) in the two wheat varieties. As can be seen from the table; TKW and HW values were decreased very sharply as a result of the increase sucking degree damage caused by the SP. These results indicate that SP, in piercing the kernel, extract part of the some composition (e.g. starch and protein) substances and it leads to reduction in kernel weight (Rashwani, 1984; Atli et al.,

1988). The same situation was observed in largeness of the samples (Table 1). Degree of sucking on kernel had effects on largeness-homogeneity values of wheat. It was clear that, significant variations ($p<0.05$) were observed for largeness and homogeneity values. The lowest result for largeness was found from 4/4 sucking degree damaged sample. Largeness of SP damaged wheat samples decreased while sucking degree on kernel increased, as observed in the TKW and HW (Table 1). These changes were similar to the findings of previous study (Dizlek et al., 2008a). 4 different wheat groups belong to Golia variety have heterogeneous structure. Wheat groups, except 4/4 SPSD, belongs to Sagittario variety have homogenous structure. It was determined that SPSD in damaged wheat bulk had limited effect on kernel size of Sagittario variety. As a result of visual inspection of SP damaged grains, these kernels were similar in size to the undamaged kernels which were observed. This case shows that the occurrence of SP damage in Sagittario cultivar may have coincided with the waxy-ripe stage of wheat (Atli et al., 1988; Lorenz and Meredith, 1988b). It was concluded that SPSD affected more the kernel size value of Golia variety, whereas Sagittario grains were affected at a limited range.

Table 1. The effects of different sunn pest sucking degree (1/4, 2/4, 3/4, and 4/4) in wheat grain on physical characteristics of two wheat varieties [(1)]

Wheat variety	Sunn pest sucking degree	Thousand kernels weight (g) [(2)]	Hectolitre weight (kg)	Large (≥2.8 mm)	Medium (2.5–2.8 mm)	Small (2.2–2.5 mm)	Undersize (≤2.2 mm)
Golia	1/4	18.9 [a]	69.0 [a]	15.0 [a]	26.8 [a]	33.1 [a]	25.1 [d]
	2/4	16.9 [b]	65.2 [b]	13.6 [b]	23.3 [b]	33.0 [a]	30.1 [c]
	3/4	15.2 [c]	60.7 [c]	10.1 [c]	23.0 [b]	33.8 [a]	33.1 [b]
	4/4	12.8 [d]	52.5 [d]	7.3 [d]	16.7 [c]	34.1 [a]	41.9 [a]
Sagittario	1/4	33.2 [a]	76.8 [a]	49.5 [a]	36.9 [a]	12.6 [c]	1.0 [d]
	2/4	29.1 [b]	70.6 [b]	46.3 [ab]	35.6 [b]	14.8 [b]	3.3 [c]
	3/4	26.9 [c]	66.4 [b]	43.3 [b]	35.3 [b]	15.9 [b]	5.5 [b]
	4/4	22.5 [d]	58.7 [c]	37.8 [c]	32.1 [c]	19.8 [a]	10.3 [a]

[(1)] Mean values in the table for the same column and same variety (Golia or Sagittario) shown with the different superscript letter are significantly different $p<0.05$.
[(2)] Calculation based on the dry matter basis.

The difference between degree of sucking 1/4 and 4/4 SP damaged group of Golia and Sagittario varieties was approximately 6 g and 11 g for kernel weight, respectively. There is nearly 16.5 kg difference in Golia and 18 kg difference in Sagittario between 1/4 and 4/4 SP damaged group in terms of HW. In terms of sucking degrees effects on TKW, HW, and largeness, differences were observed between wheat varieties. These differences were thought to be derived from genetic differences. Similarly, it was reported that there were variations in terms of quality losses originated from SP damage in wheat cultivars (Kinaci et al., 1998; Sivri et al., 2002; Kinaci and Kinaci, 2004).

TKW and HW are important quality characteristics for determining the suitability of wheat for milling (Karababa and Ozan, 1998). TKW, as a physical quality character of wheat, is positively correlated with wheat flour yield. High TKW indicates better germination and emergence of seedlings (Kinaci and Kinaci, 2004). According to Critchley (1998) and Hariri et al. (2000), the TKW of SP damaged wheat can be 8-22% and 20-24% lower than that of the undamaged kernel, respectively. In this study, considering two different wheat varieties together (Table 1), 4/4 degree of sucks on kernel caused decrease in TKW till 32% and HW till 23% compared to 1/4 degree of suck on kernel. Although researchers reported that two or three sucking were as acceptable as only one sucking (Atli et al., 1988), the results in the Table 1 indicated that sucking degree on a

kernel had effect on physical characteristics of wheat. Evaluating the obtained data together (Table 1), in general, the increase in SPSD in damaged wheat bulk caused 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 largeness properties, similar results were found for both Sagittario and Golia varieties. As expected, the 1/4 SPSD sample had higher results than the other samples for all physical quality parameters. The findings on the physical properties of wheat were consistent with the findings in the literature (Rashwani and Cardona, 1984; Critchley, 1998; Karababa and Ozan, 1998; Hariri et al., 2000; Kinaci and Kinaci, 2004; Dizlek and Islamoglu, 2009).

Chemical properties

The effects of SPSD on the chemical compositions of the wheat and flour varieties were given in Table 2. In Sagittario variety, no statistical significant ($p>0.05$) was found between different SPSD groups in terms of moisture content. In Golia variety, there were significant differences found between SPSD groups. Probably, this is resulted from SP damage providing drier, tougher, and shrivelled structure to wheat (Dizlek and Ozer, 2016) and Golia variety having relatively small grains. In the study, wheat groups did not exceed the critical moisture level, 14%, limit. When the SPSD in wheat bulk were increased, ash content and CFC of wheat were increased in both of two wheat varieties ($p<0.05$), but the rate of increase depended on variety. As a natural consequence of this measurement, the increase in SPSD in wheat bulk caused a decrease on CPC and starch content of wheat (Rashwani, 1984; Waage, 1998). In respect thereof, all sucking insects pierce the seed coat and inject saliva to solubilize the nutrients. The salivary secretions contain amylolytic and proteolytic enzymes (Table 3 and 4) that persist in the grain after feeding. Insects feed on immature wheat grains, by attacking the developing kernels and sucking the cell content to derive their food (Koksel et al., 2002).

Table 2. The effects of different sunn pest sucking degree in wheat grain on chemical compositions of two wheat varieties and they flours (%) [1]

Wheat wariety	Sunn pest sucking degree	Moisture	Ash [2]	Crude protein [2]	Starch [2]	Crude fiber [2]
Wheat						
Golia	1/4	11.1 ^{a}	2.56 ^{d}	15.4 ^{a}	62.5 ^{a}	4.8 ^{d}
	2/4	10.9 ^{ab}	2.81 ^{c}	14.7 ^{b}	62.0 ^{ab}	5.1 ^{c}
	3/4	10.8 ^{b}	3.28 ^{b}	14.5 ^{b}	61.2 ^{b}	5.7 ^{b}
	4/4	10.4 ^{c}	4.57 ^{a}	14.4 ^{c}	57.5 ^{c}	8.0 ^{a}
Sagittario	1/4	12.1 ^{a}	1.65 ^{d}	15.8 ^{a}	69.1 ^{a}	3.0 ^{c}
	2/4	12.1 ^{a}	1.81 ^{c}	15.3 ^{b}	68.0 ^{b}	2.9 ^{c}
	3/4	12.0 ^{a}	1.93 ^{b}	15.1 ^{b}	66.9 ^{c}	3.6 ^{b}
	4/4	12.1 ^{a}	2.75 ^{a}	15.1 ^{b}	63.3 ^{d}	5.5 ^{a}
Wheat Flour						
Golia	1/4	13.6 ^{a}	0.69 ^{c}	12.7 ^{a}	73.0 ^{a}	1.8 ^{d}
	2/4	13.6 ^{a}	0.70 ^{c}	12.4 ^{b}	72.5 ^{ab}	2.1 ^{c}
	3/4	13.7 ^{a}	0.75 ^{b}	11.9 ^{c}	71.4 ^{b}	2.5 ^{b}
	4/4	13.6 ^{a}	0.91 ^{a}	11.1 ^{d}	69.9 ^{c}	3.7 ^{a}
Sagittario	1/4	13.5 ^{a}	0.53 ^{c}	12.5 ^{a}	75.0 ^{a}	1.0 ^{c}
	2/4	13.6 ^{a}	0.56 ^{c}	12.2 ^{ab}	74.4 ^{a}	1.2 ^{bc}
	3/4	13.6 ^{a}	0.61 ^{b}	12.1 ^{ab}	74.0 ^{a}	1.4 ^{b}
	4/4	13.4 ^{a}	0.70 ^{a}	11.8 ^{b}	70.7 ^{b}	1.9 ^{a}

[1] Mean values in the table for the same column and same wheat or wheat flour varieties (Golia or Sagittario) shown with the different superscript letter are significantly different $p<0.05$.

[2] Calculation based on the dry matter basis.

SP feed on grains at different stages of development (Ravan et al., 2009). It was thought that the reason why CFC and ash content of Golia groups were higher than Sagittario groups, could be that SP damage tooks place in Golia group at earlier stage and so grains had relatively puny structure. Koksel et al. (2002) and Ozberk 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, resulting in smaller, lighter, and shrivelled kernels. In both of two wheat flour varieties, no statistical significant ($p>0.05$) was found between 1/4–4/4 SPSD groups in terms of moisture content. As it can be seen in the Table 2; SPSD affected the ash content of wheat's and their flours significantly. Increase in SPSD in wheat bulk caused a decrease in CPC of wheat flour groups produced from wheat having different SPSD. Kinaci and Kinaci (2004) showed that the damage caused 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 2). The increase in SPSD in wheat bulk caused a starch content decrease of wheat and flour samples in the two varieties. There were significant ($p<0.05$) differences detected between CFC of flour groups (Table 2). Accordingly, when the SPSD in wheat bulk increased, CFC of wheat flour samples increased very evidently in both varieties. The main factors that caused this status, is that when the SP damage occurs in 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 increased.

Biochemical properties

The effects of different SPSD on the biochemical characteristics of wheat are presented in Tables 3 and 4. According to the results, SPSD significantly ($p<0.05$) affected proteolytic and amylolytic enzyme activities of the two wheat varieties. It was determined that increase in SPSD in damaged wheat bulk and parallel to the increase of incubation time caused a clear and significant increase in the soluble protein quantity in sodium dodecyl sulphate (SDS) solution. This situation explains the increase of PA. Similarly, when the SPSD in damaged wheat bulk increased, AA of wheat samples was shown increase (FNV data decrease) very evidently ($p<0.05$). In general, the results obtained in both wheat varieties were in good accordance with each other (Tables 3 and 4).

Table 3. The effects of different sunn pest sucking degree in wheat grain on proteolytic enzyme activity of two wheat varieties (Spectrophotometric measurement results performed by the method proposed by Every [1991] with modification) [(1)]

Wheat variety	Sunn pest sucking degree	Incubation times (h)					
		0	1	2	3	4	5
Soluble protein quantity in SDS solution (280 nm Absorbance)							
Golia	1/4	0.1802 ^{d}	0.1991 ^{d}	0.2512 ^{d}	0.2788 ^{c}	0.3014 ^{c}	0.3326 ^{d}
	2/4	0.1842 ^{c}	0.2034 ^{c}	0.2632 ^{c}	0.2815 ^{c}	0.3099 ^{c}	0.3415 ^{c}
	3/4	0.1901 ^{b}	0.2105 ^{b}	0.2755 ^{b}	0.3102 ^{b}	0.3655 ^{b}	0.4039 ^{b}
	4/4	0.2134 ^{a}	0.2556 ^{a}	0.3226 ^{a}	0.3778 ^{a}	0.4305 ^{a}	0.4754 ^{a}
Sagittario	1/4	0.1874 ^{c}	0.2046 ^{c}	0.2559 ^{c}	0.2789 ^{b}	0.3187 ^{c}	0.3473 ^{d}
	2/4	0.1901 ^{b}	0.2078 ^{bc}	0.2601 ^{b}	0.2811 ^{b}	0.3206 ^{c}	0.3530 ^{c}
	3/4	0.1935 ^{a}	0.2115 ^{b}	0.2718 ^{a}	0.2831 ^{b}	0.3304 ^{b}	0.3688 ^{b}
	4/4	0.1952 ^{a}	0.2235 ^{a}	0.2688 ^{a}	0.2918 ^{a}	0.3451 ^{a}	0.4112 ^{a}

[(1)] Mean values in the table for the same column and same variety (Golia or Sagittario) shown with the different superscript letter are significantly different $p<0.05$.

Table 4. The effects of different sunn pest sucking degree in wheat grain on amylolytic enzyme activity of two wheat varieties [(1)]

Wheat variety	Sunn pest sucking degree	Amylase activity (CU g^{-1})	Falling number value (s)
Golia	1/4	0.139 [d]	261 [a]
	2/4	0.160 [c]	250 [b]
	3/4	0.188 [b]	234 [c]
	4/4	0.223 [a]	211 [d]
Sagittario	1/4	0.112 [d]	268 [a]
	2/4	0.125 [c]	254 [b]
	3/4	0.146 [b]	241 [c]
	4/4	0.178 [a]	213 [d]

[(1)] Mean values in the table for the same column and same variety (Golia or Sagittario) shown with the different superscript letter are significantly different $p<0.05$.

Technological properties

The effects of different SPSD on the technological characteristics (WGC, DGC, GIV, ZST, DZST, and FNV) of wheat flours are given in Table 5. It was determined that WG of varieties could not be washed from the 2/4, 3/4, and 4/4 SPSD groups due to the intensive proteolytic enzyme activity. For this purpose, DGC and GIV values of these groups could not be determined (Table 5). Similarly, Diraman (2009) reported that; wet gluten could not be washed from the 100% bug-damaged Bezostaja-1 wheat sample because of the intensive proteolytic enzyme activity resulting from SP damage. Therefore, GIV could not be carried out for SP damaged samples in the study of Diraman (2009). The effects of sucking degrees on the kernels affected ZST values significantly ($p<0.05$) in both varieties. Degree of sucking on kernel had relatively smaller effects on DZST. ZST in particular has been practically and widely used for determination of gluten quality by the millers (Diraman, 2010). Sedimentation tests (ZST and DZST) were realized to determine whether the wheat was exposed to SP damage, or to what extent it was (Dizlek and Islamoglu, 2015). WGC and DGC were used for determining gluten quantity. GIV was used for determining gluten quality. DZST is the most important indication of the SP damage level of wheat kernels (Diraman, 2010). In this study, ZST values decreased dramatically, but DZST values did not decrease very sharply with the increase of SPSD in two wheat varieties (Table 5), because all experimental materials included intensive proteolytic enzyme activity resulting from SP damage (Kretovich, 1944; Every et al., 1989; Diraman, 2009).

Table 5. The effects of different sunn pest sucking degree in wheat grain on physicochemical properties of two wheat flour varieties [(1)]

Wheat variety	Sunn pest sucking degree	Wet gluten content (%)	Dry gluten content (%)	Gluten index value (%)	Zeleny sedimentation test (mL) [(2)]	Delayed zeleny sedimentation test (mL) [(2)]	Falling number value (s) [(2)]
Golia	1/4	27.7	9.1	14	16.3 [a]	6.5 [a]	310 [a]
	2/4	Could not be washed	-	-	11.2 [b]	3.1 [b]	296 [b]
	3/4	Could not be washed	-	-	4.0 [c]	3.0 [b]	270 [c]
	4/4	Could not be washed	-	-	3.2 [d]	3.0 [b]	238 [d]
Sagittario	1/4	28.1	9.1	24	14.0 [a]	3.8 [a]	301 [a]
	2/4	Could not be washed	-	-	9.1 [b]	3.1 [a]	293 [b]
	3/4	Could not be washed	-	-	3.3 [c]	3.0 [a]	272 [c]
	4/4	Could not be washed	-	-	3.1 [c]	2.9 [a]	241 [d]

[(1)] Mean values in the table for the same column and same variety (Golia or Sagittario) shown with the different superscript letter are significantly different $p<0.05$.
[(2)] Adjusted to 14% moisture basis.

With the evaluation of FNV, it was found that AA increased depending on increasing level of SPSD in damaged wheat bulk ($p<0.05$). This pointed out that there was amylase in SP secretion, which was compatible with findings of some early researchers (Kretovich, 1944; Atasanova and Popova, 1968; Lorenz and Meredith, 1988a; Dizlek et al., 2008b) and Table 4.

In practice 1/4, 2/4, 3/4, and 4/4 sucked kernels are considered in the same group. Results in Tables 1–5 show that, degree of sucking in wheat grain plays an important role in determining quality characteristics of wheat. The results of this study clearly demonstrated that the quality parameters of wheat varieties and their flours decreased by the increase in the SPSD on kernel in damaged wheat bulk. For this reason, particularly 3/4 and 4/4 sucking kernel have to be handled in different groups than 1/4 and 2/4 sucking kernel. It was found that results also depended on wheat varieties and Golia variety was more sensitive to SPSD than the Sagittario.

As a result, when the SPSD in damaged wheat bulk increased, ash content and CFC of wheat were increased, but starch content and CPC of wheat were decreased in both of two wheat varieties. However, the rate of increase or decrease depended on variety. Sucking degree significantly ($p<0.05$) affected TKW and HW of wheat varieties as expected. PA, AA, CFC, and ash content of samples increased sharply; CPC and starch content decreased partially; FNV and ZST values decreased depending on increasing level of sucking degree in SP damaged wheat mass. SPSD in damaged wheat bulk, significantly affected TKW, HW, ZST, and PA of wheat varieties ($p<0.05$). Briefly, we concluded that sucking degree on the kernel is important in affecting quality characteristics of wheat varieties.

CONCLUSIONS

The degree of sucking by SP in damaged wheat bulk plays an important role in quality characteristics of wheat. The increase in SPSD (from 1/4 to 4/4) in damaged wheat bulk caused a clear and significant ($p<0.05$) decrease in physical, biochemical, and technological characteristics of the varieties. Golia variety was more sensitive than the Sagittario variety in terms of SPSD. Decrease in quality characteristics started from 1/4 SPSD and wheat-flour properties were reduced significantly after 2/4 SPSD in both varieties. It was concluded that in order to conduct the SP sucking analysis correctly, sucking degree on a kernel must be taken into consideration, as well as the sucking number and sucking ratio. Our results will provide benefits for elaborating instructions for industry in order to use SP damaged wheat and to elect additives used in preparing wheat blends and/or making bread. SPSD on the grains affected the quality in two bread wheat varieties significantly. Thus, sucking degree should be paid attention for the classification of the damaged grains and 1/4, 2/4, 3/4, and 4/4 sucked grains should not be evaluated in the same way. Particularly, characteristics of 1/4 part of sucking kernel by SP dramatically differ from 3/4 and 4/4 part of sucking kernel. So, in classification of the SP damaged grains, at least 1/4 and 2/4 sucked grains should be classified in one group, and 3/4 and 4/4 sucked grains should be classified as another group. Also it would be useful to give the proportion of these two groups in the SP damaged wheat mass.

The results of this study also clearly showed that the insect damaged wheat kernels can be classified according to sucking degree as protease activity, and this will be meaningful. Alternatively, sucking degree can be expressed not only by physical, chemical, biochemical, and physicochemical analyses of wheat (flour), but also according to protein damage, such as SDS-PAGE analysis. Therefore, technological effects of SPSD damage should be investigated by other important analyses about quality with further research.

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