

The effects of sunn pest (*Eurygaster integriceps*) damage ratios on bread making quality of wheat with and without additives

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RESEARCH ARTICLE

Abstract

Sunn pest (SP) is the most important detrimental insect species for wheat in Turkey and neighbouring countries. SP reduces both wheat yield and quality. The aim of this study was to determine the effects of sunn pest damage ratios (SPDR) on baking quality of two bread wheat varieties (Golia and Sagittario). Experimental materials were prepared by separating damaged kernels from wheat bulk and then by mixing sound kernels at different ratios of 0 (control), 2, 4, 8, 12, 16 and 100%. A standard bread making procedure was applied to produce bread with (diacetyl tartaric acid esters of mono and diglycerides, transglutaminase, citric acid, and L-ascorbic acid) and without additives. Fundamental characteristics of bread samples were determined. It was observed that SPDR in wheat bulk played an important role in baking quality of both varieties. An increase in SPDR caused a decrease on bread characteristics of both wheat varieties, but the rate of decline in baking quality depended on the variety. Weight loss and wideness of bread samples sharply increased, while yield, height, pore structure, and crumb softness values decreased accurately depending on increasing SPDR level. 2% SPDR did not negatively affect dough and bread quality, however when the SPDR was more than 2% dough and bread characteristics significantly declined. Using additives in bread making improves bread quality, especially bread at (higher) SPDR.

Keywords: sunn pest damage ratios, wheat, baking quality, bread, additives

1. Introduction

Wheat is grown in 221,615,921 ha throughout the World, producing 728,966,757 tons of grains in 2014. Wheat takes the first place in field crops in Turkey with 7,820,750 ha growing area and a production of 19,000,000 tons in 2014 (Anonymous, 2015a). It contains most basic nutrients to feed the human population. Particularly, from North Africa to Central Asia, it provides about half of the total dietary calories (Reynolds *et al.*, 2008).

Damage to wheat and its baking quality due to insects has been reported from all over the world (Lorenz and Meredith, 1988). Bug damage is usually associated with insects of the genera *Eurygaster*, *Aelia*, and *Nysius*. All these insects are sucking insects, piercing the developing grain with their stylets. During feeding they inject saliva (proteolytic enzymes) in to the wheat kernel to dissolve

plant proteins, especially wheat gluten proteins, and cause important losses to millers, bakers, and economies (Hosseininaveh *et al.*, 2009; Konarev *et al.*, 2011; Kretovich, 1944; Lorenz and Meredith, 1988). In Turkey, thousands of dollars are spent annually to control sunn pest (SP, *Eurygaster* spp.). According to 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 allocated to coarse wheat (Anonymous, 2015b).

Bug-damaged wheat causes reduction in flour quality, giving a softer dough and subsequently flat bread with low volume, rough crust surface, sharp edges to loaf and unsatisfactory texture (Every, 1992; Hariri *et al.*, 2000; Lorenz and Meredith, 1988). 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 (Dizlek and Özer, 2016a; El-Haramein *et al.*, 1984; Every *et al.*, 1989; Hariri *et al.*, 2000; Karababa and Ozan, 1998; Köksel *et al.*, 2002; Kosmin, 1933; Matsoukas and Morrison, 1990; Sivri *et al.*, 2004; Vasileva *et al.*, 1996; Yakovenko *et al.*, 1973). Different researchers reported very different sunn pest damage ratios (SPDR) in the range of 0.3 to 10%, leading to confusion on the SPDR level destroying the technological quality (bread and pasta making) of wheat (Dizlek and Özer, 2016a). These differences between the studies may be explained by the different insect species found to infest wheat cultivars, population density of the insects, weather conditions, water availability, duration of the crop growing period, occurring stage of insect damage, sucking degree (1/4, 2/4, 3/4, and 4/4), sucking number on a kernel (single, double, triple) by insects, and wheat cultivar characteristics (Dizlek and Islamoglu, 2009, 2015; Karababa and Ozan, 1998). On this subject, it has been well documented that with an increasing ratio of damaged kernels in wheat mass, the quality characteristics of wheat's decrease (Dizlek and Özer, 2016a; ICARDA, 1983; Karababa and Ozan, 1998; Köksel *et al.*, 2009; Ozderen *et al.*, 2008).

The deterioration of the quality of flour of wheat damaged by SP can be demonstrated by physical, chemical, technological and rheological analysis (Diraman, 2010), however, applying bread making experiments by using a standard method and to determine the characteristics of the obtained bread is the best way (Atli *et al.*, 1988a; Every, 1992; Meredith, 1970; Swallow and Every, 1991; Uluoz, 1965).

The aim of the present study was to determine (1) at which extent adverse effects of SPDR in wheat bulk on baking quality (parameters especially related to fundamental bread characteristics in order to predict maximum allowable amount of damaged kernels in the wheat varieties) and (2) to examine the possibilities to negate the adverse effects by using additives in bread making. For this purpose, baking experiments on two wheat varieties, Golia and Sagittario, at different SPDR were performed.

2. Materials and methods

Wheat groups

In this study, insect-damaged two bread wheat varieties, Golia and Sagittario purchased from Deveciogullari and Demir Trading Companies, (Nurdagi, Gaziantep, Turkey), respectively, were used. The SPDR of Golia and Sagittario were 3.92 and 7.8%, respectively (Dizlek and Özer, 2017). SP damage in these wheat varieties was caused for 98% by *Eurygaster integriceps* and 2% by *Eurygaster maura* (Dizlek and Özer, 2017).

Preparation of blending (wheat and flour) groups

Experimental materials were prepared according to Dizlek and Özer (2017). Briefly, SP damaged and sound kernels were separated manually from each wheat variety. The damaged wheat kernels were then added back to the sound kernels at 0 (only sound kernels), 2, 4, 8, 12, 16 and 100% (only SP kernels) ratio, and mixed thoroughly to make them homogeneous. Blended wheat groups were tempered to 16.5% moisture content for 32 h and milled separately. Obtained flour samples were sifted in order to keep the ash content of flour low. These flour samples were used for bread making trials. The control flour of Golia and Sagittario had 15.36% and 14.8% moisture, 0.69% and 0.56% ash, 9.8% and 10% dry gluten content, 30.6 ml and 28.3 ml Zeleny sedimentation value, 37.7 ml and 28.3 ml delayed Zeleny sedimentation value, 100% and 97% gluten index, 456 s and 412 s falling number, 59.2% and 59.4% farinograph water absorption, 2.5 min and 5.8 min development time, 14.4 min and 7.5 min stability, 603 B.U. and 259 B.U. extensograph maximum resistance to extension, 101 mm and 171 mm extensibility, 81 cm² and 68 cm² energy, respectively (Dizlek and Ozal, 2016, 2017).

Baking chemicals and additives

Transglutaminase (TG; TG Activa WM, 100 U/g) was kindly provided from Ajinomoto Co., Inc. (Tokyo, Japan), L-ascorbic acid (L-AA; food grade, ELCO C-100 K) and citric acid (CA; EMCEtric AP) were purchased from Muhlenchemie GmbH & Co. KG (Ahrensburg, Germany), diacetyl tartaric acid esters of mono and diglycerides (DATEM; Safmill T-310) and bread yeast were supplied from LeSaffree-Ozmaya Co. (Adana, Turkey). Salt was purchased locally. Potable water supplied within the campus of University of Cukurova (Adana, Turkey). TG, L-AA, CA, and DATEM were selected to overcome the destroyed gluten proteins caused by the different SPDR in flour. In the study, all these additives, especially TG enzyme, were used to alter the molecular structure and to improve the functional characteristics of gluten.

Dough preparation and bread making studies

The appropriate values and practices for some basic bread making procedures using SPDR flour and applied in this study are described in Dizlek and Özer (2016b). The standard baking formula used consisted of: flour 100%, water (for Golia 55.4-59.2%, for Sagittario 56.0-59.4%), yeast 3%, and salt 2% (these dough ingredients were expressed as percentage of base flour weight). The amount of water in each formula was determined by the farinograms (Approved Method 54-21.02; AACCI, 2000). The additives added to the standard formula consisted of 0.5% DATEM, 0.15% TG, 100 mg/kg CA and 75 mg/kg L-AA. Bread making

experiments were carried out in duplicate with 28 different formulations using 2 wheat flour varieties, 7 SPDR and with/without additives.

As it is very difficult and time consuming to (manually) create the SPDR wheat groups, bread making experiments carried out in farinograph device mixing bowl (Brabender, Duisburg, Germany) which enables preparing dough using a small flour sample (Bauer *et al.*, 2003). For this purpose, 300 g flour (14% moisture basis), 9 g yeast, 6 g salt and the amount of water needed according to the farinograph water absorption value of water for each SPDR level were used to prepare the dough.

Bread making tests were done using a mechanical dough development method. Ingredients were optimally mixed until dough development, scaled into pieces 100 g dough weight, hand-rounded, moulded and rested (fermentation). Desired final dough temperature was controlled at 25 ± 1 °C by adjusting the water temperature. Dough samples were not subjected to two separated fermentations (as initial and final fermentations) but only subjected to a single fermentation for 120 min. The fermentation procedure was carried out in the fermentation chamber made of heat-insulated material and equipped with heating system and steam unit. Baking was carried out in a 'Wiesheu EBO 1-64R' model stone floor oven (Wiesheu GMBH, Affalterbach, Germany) for 16 min at 260 °C. The oven was preheated for several minutes until it reached the pre-set temperature. After baking, bread samples were cooled for 1 h at room temperature, and then put into plastic bags and stored at 25 °C until bread analyses. During dough preparation, samples of Sagittario (with/without additives) were kneaded 1 min less (10 min) than Golia, because the stability and resistance to extension values of Sagittario flour were lower than for Golia flour (Dizlek and Özer, 2017). Also, the additives dough prepared with Sagittario was baked longer (18.5 instead of 16 min) at 260 °C. The procedure followed for bread making was diagrammatised in Figure 1.

Bread analysis

Analysis of bread was performed as described by Dizlek and Özer (2016b). Briefly, volume of bread was measured by rapeseed displacement method as cm^3 (AACCI Method 10-05.01; AACCI, 2000). The weights of bread samples were determined using a scale. The volume of the bread made from 100 g flour on the basis of 14% moisture was calculated as the volume yield (Gül *et al.*, 2009). Similarly, the weight of bread produced with 100 g flour based on a moisture content of 14% was calculated as the bread yield. Percentage weight loss (Dizlek, 2015) was measured by determining the initial weight of the dough (100 g) and subtracting the weight of baked bread after 6 h cooling (W1). The height

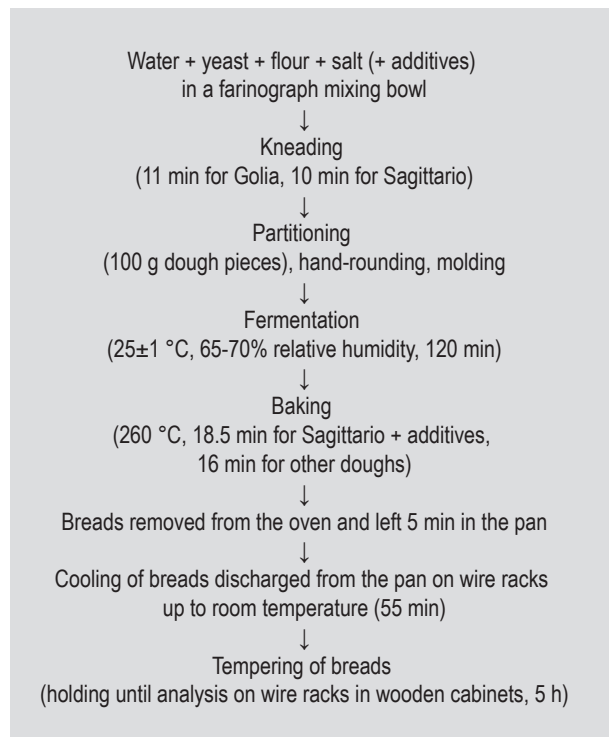


Figure 1. Processing steps applied in bread making experiments.

and width of bread samples were determined by a digital calliper and height/width ratio was calculated according to Hosenev (1986). Crumb-pore structure was evaluated using the Dallman scale (Turkish Standards Institute, 1987). SUR penetrometer PNR 6 (SUR Berlin, Germany) with 200 g of total test weight was used to determine the crumb firmness (Özer and Altan, 1995). Crumb firmness was measured within 6 and 24 h after removal from the oven, while all other analyses were conducted within 6 h after bread was removed from the oven.

In addition, the effects of various SPDR on dough characteristics (with and without additives) were determined by subjective evaluations just after kneading and fermentation of the dough. In the study, bread samples of SP damaged groups (2, 4, 8, 12, 16 and 100%) were compared with bread samples made from sound flour (0%=control).

Statistical analysis

All experiments (bread making trials and analyses) were carried out in two replicates. Analyse of variance (ANOVA) was conducted using SAS v6.12 (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 ($P < 0.05$). In the study, bread produced without additive and constant additives were subjected to separate statistical analyses.

3. Results and discussion

Bread produced without additives

The effects of various levels SPDR on quality characteristics of dough and bread samples containing no additives are given in Tables 1 and 2. Overall and vertical cross-sectional view of the Golia and Sagittario varieties bread samples produced without additives are presented in Figures 2 and 3, respectively. Gluten quality declined with an increase in SPDR in wheat mass and elasticity and strength of the dough decreases, while softening and adhesive properties increased. Dough samples from SPDR flour showed slack, runny and spread characters (Table 2). An increase in SPDR in wheat bulk caused a decrease in bread yield, swelling (height) and height/width values, and an increase in bread weight loss and width ($P<0.05$) (Table 1). In the 16% and 100% SPDR Sagittario groups and the 100% SPDR Golia group bread could not be produced due to the poor gluten (quality) caused by the intensive SP damage. Consequently, bread measurements of these groups could not be taken.

The bread yield and height values obtained from the 12% SPDR Sagittario group were less than that of the 0% control group (about 21 and 71%, respectively). The values for

weight loss and width for the same group increased by 82 and 31%, respectively. The height/width ratio of the bread decreased with an increase of SPDR in the wheat bulk. This decrease was maximal in 12% SPDR group with a reduction of 79% from the control (Table 1). Unlike bread made from Sagittario, SPDR in wheat bulk had relatively limited effect on bread yield and weight loss in bread samples of Golia. Volume yield, specific volume, pore structure and penetrometer values of bread samples decreased in Sagittario ($P<0.05$) with an increase in SPDR. Similar results were obtained from bread making experiments with Golia flour (Table 1). The most dramatic effect of the SPDR increase is shown by the crumb-pore structure of the produced bread. In the 12% and 16% SPDR Golia groups and the 8% and 12% SPDR Sagittario groups, penetrometer values could not be measured as the thickness (height) of the bread slices did not exceed 28 mm (Table 1).

Dizlek and Özer (2016a) determined that SPDR had a significant ($P<0.05$) effect on wheat (flour) quality. They showed that one of the most important wheat characteristic, gluten quality, was significantly destroyed when SPDR in wheat bulk increased. With the evaluation of technological features of flour-dough that give information about bread quality, they concluded that the baking quality of flour

Table 1. The effects of sunn pest damage ratios (SPDR) on characteristics of bread produced without additives.^{1,2}

SPDR (%)	Bread yield (g/100 g flour)	Weight loss (%)	Height (mm)	Width (mm)	Height/width ratio	Volume yield (cm ³ /100 g flour)	Specific volume (cm ³ /g)	Crumb-pore structure (0-8 score)	Penetrometer values (1/10 mm)	
									6 h	24 h
Golia										
0 (control)	139.2 ^a	15.3 ^d	54.0 ^a	95.3 ^f	0.57 ^a	502 ^c	3.62 ^c	6.6 ^a	53 ^c	38 ^c
2	136.1 ^b	16.5 ^c	52.8 ^b	104.3 ^e	0.51 ^b	616 ^b	4.49 ^b	6.5 ^a	68 ^b	47 ^b
4	134.4 ^b	16.8 ^c	51.2 ^c	109.4 ^d	0.47 ^c	630 ^a	4.67 ^a	6.1 ^a	74 ^a	51 ^a
8	130.6 ^c	18.8 ^b	30.3 ^d	114.1 ^c	0.27 ^d	422 ^d	3.22 ^f	3.9 ^b	25 ^d	17 ^d
12	122.7 ^d	23.5 ^a	23.4 ^f	124.7 ^a	0.19 ^f	405 ^e	3.29 ^e	2.5 ^c	.3	.3
16	124.0 ^d	23.0 ^a	24.6 ^e	122.0 ^b	0.20 ^e	423 ^d	3.40 ^d	2.0 ^d	.3	.3
100	Dough could not be prepared so bread could not be produced									
Sagittario										
0 (control)	132.3 ^a	19.5 ^d	59.5 ^a	106.2 ^e	0.56 ^a	682 ^a	5.20 ^a	7.0 ^a	58 ^a	42 ^a
2	131.4 ^a	19.8 ^d	51.6 ^b	109.9 ^d	0.47 ^b	648 ^b	4.95 ^b	6.7 ^{ab}	53 ^b	40 ^b
4	128.3 ^b	21.5 ^c	41.9 ^c	116.3 ^c	0.36 ^c	619 ^c	4.84 ^c	5.3 ^c	32 ^c	23 ^c
8	114.7 ^c	29.0 ^b	21.0 ^d	130.4 ^b	0.16 ^d	501 ^d	4.33 ^d	3.3 ^d	.3	.3
12	104.2 ^d	35.5 ^a	17.3 ^e	139.4 ^a	0.12 ^e	416 ^e	3.95 ^e	1.3 ^e	.3	.3
16	Dough could not be prepared so bread could not be produced									
100	Dough could not be prepared so bread could not be produced									

¹ The dough formula for each SPDR was similar and consisted of: flour (100 g) + water (as farinograph water absorption value) + yeast (3 g) + salt (2 g).

² Mean values in the same column and for same wheat variety with the different superscript letters are significantly different ($P<0.05$).

³ Values could not be measured because of the thickness (height) of the bread slices was less than 28 mm.

Table 2. Subjective evaluations of dough samples prepared with sunn pest damage ratios (SPDR) without additives.¹

	SPDR (%)	Dough characteristics
Golia	0	not adhesive, elastic structure, easy to process (handle), not miss out gas
	2	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	4	less adhesive, viscoelastic structure, a little difficult to handle, not miss out gas
	8	adhesive, soft, difficult to handle, miss out gas
	12	very adhesive, difficult to give shape, very soft, very difficult to handle, miss out a lot of gas, there were obvious slits and point by point holes on the surface
	16	very excessive adhesive, very difficult to give shape, excessive soft, very difficult to handle, miss out a lot of gas, process able only by treating with plenty of flour, there were obvious slits and point by point holes on the surface, the top surface was not flat, bumpy
Sagittario	0	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	2	less adhesive, viscoelastic structure, easy to handle, not miss out gas
	4	adhesive, soft, difficult to handle, miss out little gas
	8	very adhesive, difficult to give shape, very soft, very difficult to handle, miss out a lot of gas, there were slits and point by point holes on the surface
	12	very excessive adhesive, runny, very difficult to give shape, excessive soft, miss out a lot of gas, process able only by treating with plenty of flour, there were slits and point by point holes on the surface, the top surface was not flat, bumpy
	16	adhered the kneader, strength decrease to applied to the pallets, very excessive soft, runny and adhesive structure, impossible to process by hand and machine

¹ The dough formula for each SPDR was similar and consisted of: flour (100 g) + water (as farinograph water absorption value) + yeast (3 g) + salt (2 g).

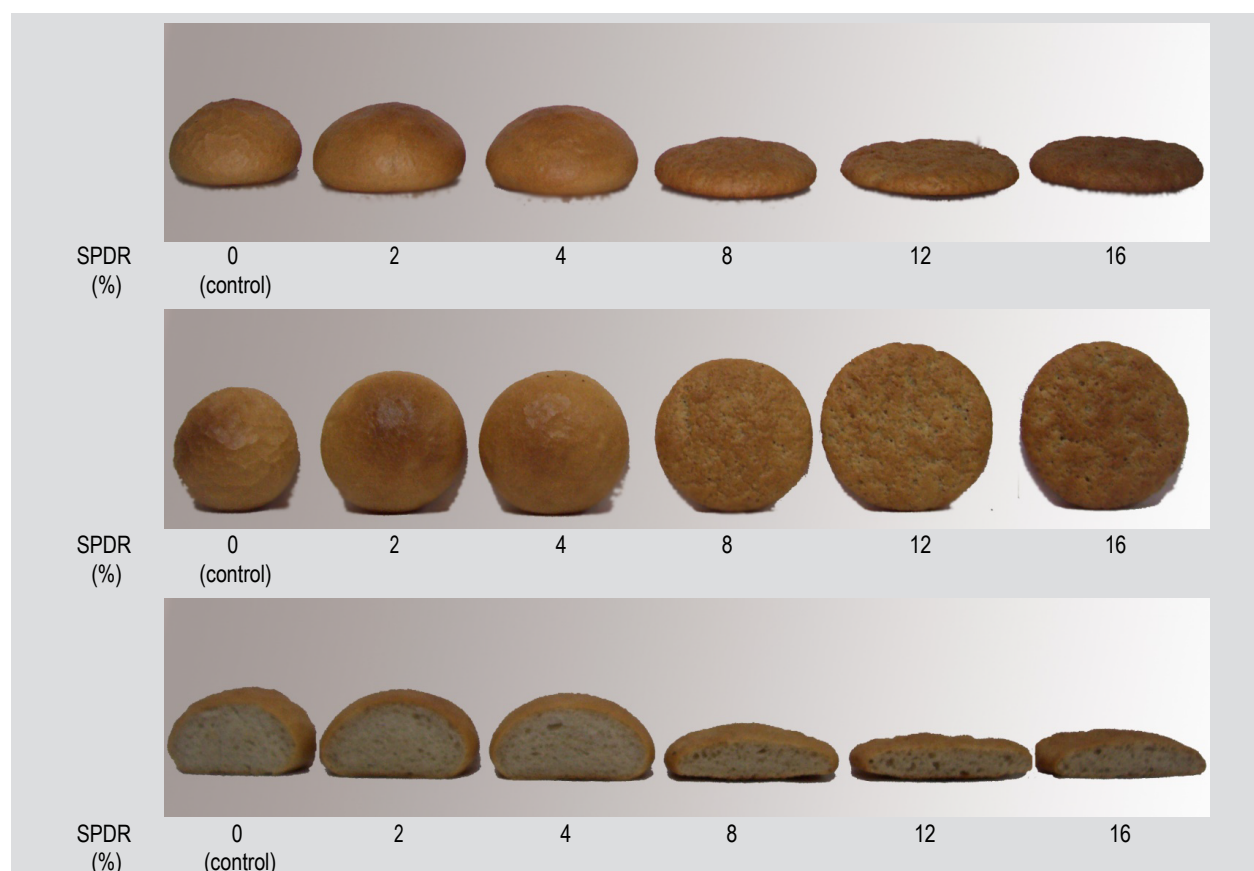


Figure 2. Overall and vertical cross-sectional view of bread samples produced with different sunn pest damage ratios (SPDR) Golia flour without additives.

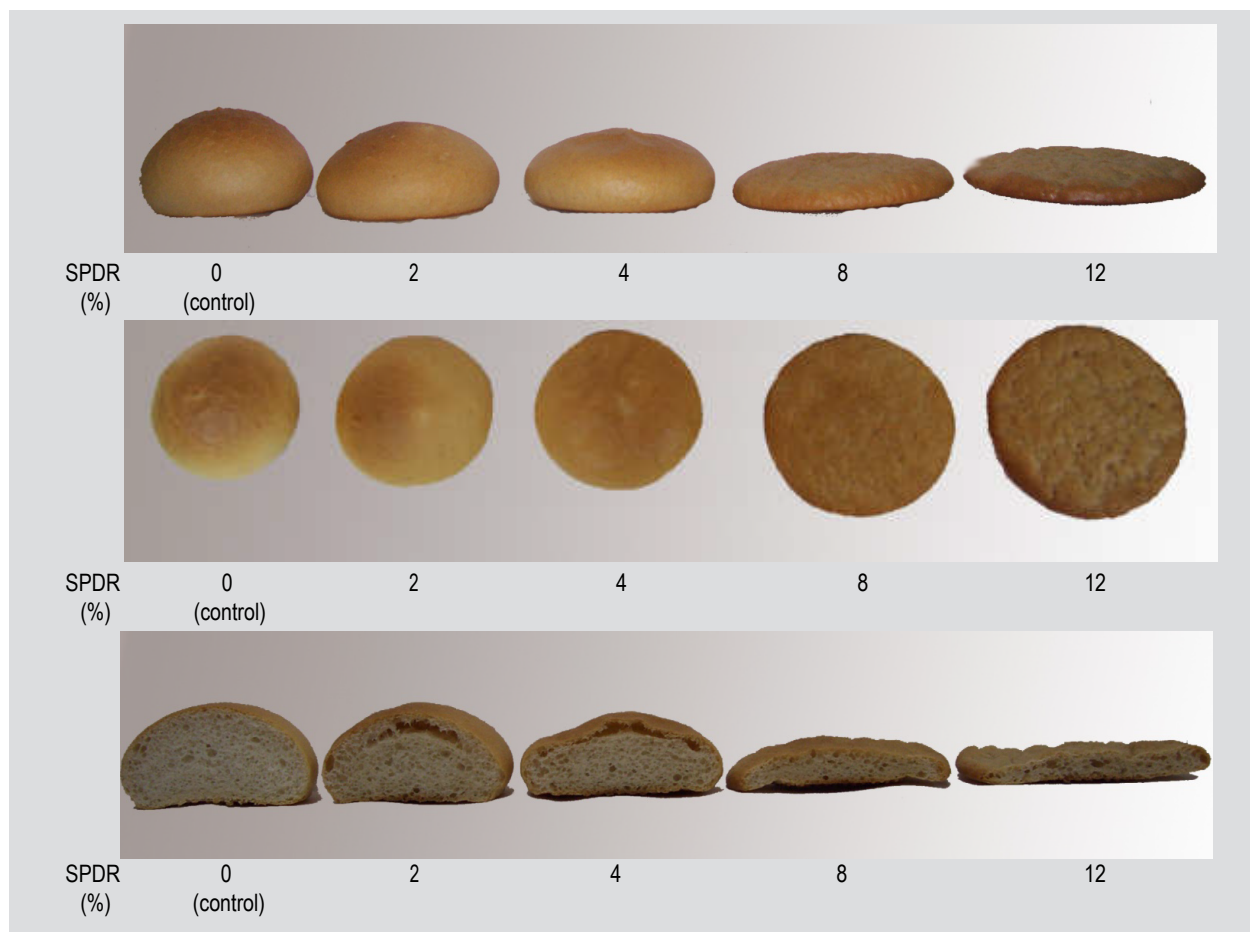


Figure 3. Overall and vertical cross-sectional view of bread samples produced with different sunn pest damage ratios (SPDR) Sagittario flour without additives.

samples was severely affected by the level of SPDR. Gluten quality (degradation of protein structure in SP flour) was affected more than the amount of gluten by increasing SPDR. In a similar manner, Olanca *et al.* (2009) suggested that SP protease caused depolymerisation and/or disaggregation of polymeric proteins that lowered their average molecular size. This flour quality reduction can be attributed to the effect of enzymes that are injected in the kernels by SP (Every *et al.*, 1989; Kretovich, 1944).

The subjective evaluation, made just after kneading and fermentation of dough (Table 2), indicated that the dough characteristics (i.e. not adhesive, (visco)elastic structure, easy to process (handle), and not miss out gas) were normal in the control sample as well as in the 2% SPDR damaged bulk. Dough became more adhesive, soft, difficult to handle, miss out gas form by increasing SPDR up to 8-12%. At 12% SPDR, dough was excessively adhesive, difficult to give shape, very soft, very difficult to handle, miss out a lot of gas, and there were obvious slits and point by point holes on the surface. At 16% SPDR, dough had very negative characteristics; it could only be handled using plenty of flour, it adhered the kneader, and was impossible to process by hand and machine. Similar

results were found for both Golia and Sagittario varieties (Table 2). In a study carried out by ICARDA (1983), for the purpose of counteracting SP damage to wheat flour baking quality, proteolytic enzymes made the dough collapse and it became too weak to produce good quality bread. Large holes and tears appeared in the dough and the Arabic bread (khobz) would not rise in the oven.

Bread weight was reduced by increase of the percentage SP infected kernels in wheat mass. The main reason of these changes were thought to be the spread of the dough base due to SP damage, more penetration of the oven heat into the dough by expansion (spread) of the surface area of dough and fermentation loss. Interestingly, the quality of the bread of Golia made with 12% SPDR was worse than the bread made with 16% SPDR (Table 1). This was also found for the bread volume values. Likely, the use of extra flour (needed for handling the 16% SPDR dough) and the bumpy top-structure of the dough caused this situation.

Among the bread samples produced without additives, bread produced with up to 4% SPDR for Golia, and 2% SPDR for Sagittario could be acceptable. The bread

quality with higher SPDR levels significantly declined and became unacceptable. All bread characteristics, particularly height, pore structure and crumb softness of bread, were significantly affected ($P < 0.05$) by the level of SPDR in wheat bulk. Therefore, it is most convenient to use a critical threshold value of 2% SPDR in bread making.

Atli *et al.* (1988a) determined that when SPDR was higher than 9%, gluten could not be washed and bread could not be produced. They observed that when SPDR increased, dough turned into a runny structure that was impossible to process by hand. Every (1991) prepared dough from blends of 0, 12, 25, 50, 75 and 100% bug (*Nyctelia huttoni*) damaged flour with sound flour. He made bread according to two different (mechanical dough development and bulk fermentation) bake test systems. He found that, for both bread making methods, the increase in proteinase activity in flour blends resulted in a decrease in dough and bread characteristics. Every (1992) reported that, when bug damaged wheat was used for bread production the protease enzymes destroyed the gluten structure, resulting in slack, sticky dough samples and loaves of characteristically poor volume (low bake score values) and texture (rough crust surface, sharp edges and coarsened crumb texture). Karababa and Ozan (1998) reported that, due to the dough structure, bread scores could not be taken when there were >7% the SP damaged

kernels in the sample. The samples with <7% damaged kernels gave the low volume and coarse texture loaves of bread. Our results were consistent with these studies, with some minor differences. These could be attributed to infestation of the wheat cultivars by the different insects (*Eurygaster*, *Aelia*, and *Nyctelia*), genetic differences between the wheat varieties in terms of the baking quality, and the use of different bread making procedures.

Bread produced with additives

The effects of various SPDR on quality characteristics of dough and bread containing additives are given in Tables 3 and 4. Overall and vertical cross-sectional views of Golia and Sagittario bread samples produced with additives are presented in Figure 4 and 5, respectively. For comparison, bread samples of Sagittario without and with additives are shown in Figure 6. The SPDR increase to (4%) only limitedly affected the bread qualities, effects became evident at 8%, and were very negative at 12% and 16% ($P < 0.05$). The use of additives relatively improved the dough (subjective evaluations shown in Table 4) and bread characteristics (Table 3).

The use of additives in bread made with 0% SPDR Golia and Sagittario groups seems excessive to the dough. The volume

Table 3. The effects of sunn pest damage ratios (SPDR) on characteristics of bread produced with additives.^{1,2}

SPDR (%)	Bread yield (g/100 g flour)	Weight loss (%)	Height (mm)	Width (mm)	Height/width ratio	Volume yield (cm ³ /100 g flour)	Specific volume (cm ³ /g)	Crumb-pore structure (0-8 score)	Penetrometer values (1/10 mm)	
									6 h	24 h
Golia										
0 (control)	142.6 ^a	13.5 ^e	62.6 ^a	97.8 ^f	0.64 ^a	597 ^b	4.20 ^d	6.6 ^a	90 ^c	71 ^c
2	140.3 ^b	14.3 ^d	63.5 ^a	103.1 ^e	0.62 ^b	685 ^a	4.86 ^b	6.8 ^a	117 ^b	97 ^b
4	136.2 ^c	16.0 ^c	62.1 ^a	104.9 ^d	0.59 ^c	691 ^a	5.06 ^a	6.8 ^a	126 ^a	107 ^a
8	135.1 ^c	16.3 ^c	47.7 ^b	107.7 ^c	0.44 ^d	592 ^b	4.36 ^c	5.8 ^b	79 ^d	61 ^d
12	132.5 ^d	17.8 ^b	34.3 ^c	110.9 ^b	0.31 ^e	465 ^c	3.50 ^e	3.2 ^c	47 ^e	33 ^e
16	128.9 ^e	20.3 ^a	28.8 ^d	121.0 ^a	0.24 ^f	447 ^d	3.45 ^f	2.2 ^d	29 ^f	21 ^f
100	Dough could not be prepared so bread could not be produced									
Sagittario										
0 (control)	131.9 ^a	20.0 ^c	62.8 ^a	109.7 ^d	0.57 ^a	817 ^{ab}	6.17 ^b	7.5 ^a	101 ^a	82 ^a
2	130.2 ^{ab}	20.8 ^{bc}	59.5 ^b	114.1 ^c	0.52 ^b	842 ^a	6.50 ^a	6.5 ^b	103 ^a	82 ^a
4	130.0 ^{ab}	20.8 ^{bc}	55.0 ^c	110.7 ^d	0.50 ^c	764 ^c	5.90 ^c	5.5 ^c	95 ^b	75 ^b
8	126.1 ^b	22.3 ^b	41.0 ^d	119.0 ^b	0.34 ^d	687 ^d	5.40 ^d	4.5 ^d	53 ^c	38 ^c
12	117.5 ^c	27.5 ^a	28.4 ^e	127.4 ^a	0.22 ^e	556 ^e	4.69 ^e	3.0 ^e	23 ^d	17 ^d
16	115.9 ^c	28.3 ^a	29.0 ^e	127.0 ^a	0.23 ^e	560 ^e	4.77 ^e	2.0 ^f	23 ^d	16 ^d
100	Dough could not be prepared so bread could not be produced									

¹ The dough formula for each SPDR was similar and consisted of: flour (100 g) + water (as farinograph water absorption value) + yeast (3 g) + salt (2 g) + diacetyl tartaric acid esters of mono and diglycerides (0.5 g) + transglutaminase (0.15 g) + citric acid (0.01 g) + L-ascorbic acid (0.0075 g).

² Mean values in the same column and for same wheat variety with the different superscript letters are significantly different ($P < 0.05$).

Table 4. Subjective evaluations of dough samples prepared with sunn pest damage ratios (SPDR) with additives.¹

	SPDR (%)	Dough characteristics
Golia	0	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	2	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	4	slightly adhesive, viscoelastic structure, easy to handle, not miss out gas
	8	adhesive, viscoelastic structure, relatively difficult to handle, miss out little gas
	12	adhesive and soft structure, difficult to handle, miss out gas
	16	very excessive adhesive and soft structure, very difficult to handle, miss out a lot of gas
Sagittario	0	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	2	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	4	not adhesive, viscoelastic structure, easy to handle, not miss out gas
	8	slightly adhesive, viscoelastic structure, relatively difficult to handle, miss out little gas
	12	adhesive and soft structure, difficult to handle, miss out gas, there were slits and point by point holes on the surface
	16	very excessive adhesive and soft structure, very difficult to handle, miss out a lot of gas, there were slits and point by point holes on the surface

¹ The dough formula for each SPDR was similar and consisted of: flour (100 g) + water (as farinograph water absorption value) + yeast (3 g) + salt (2 g) + diacetyl tartaric acid esters of mono and diglycerides (0.5 g) + transglutaminase (0.15 g) + citric acid (0.01 g) + L-ascorbic acid (0.0075 g).

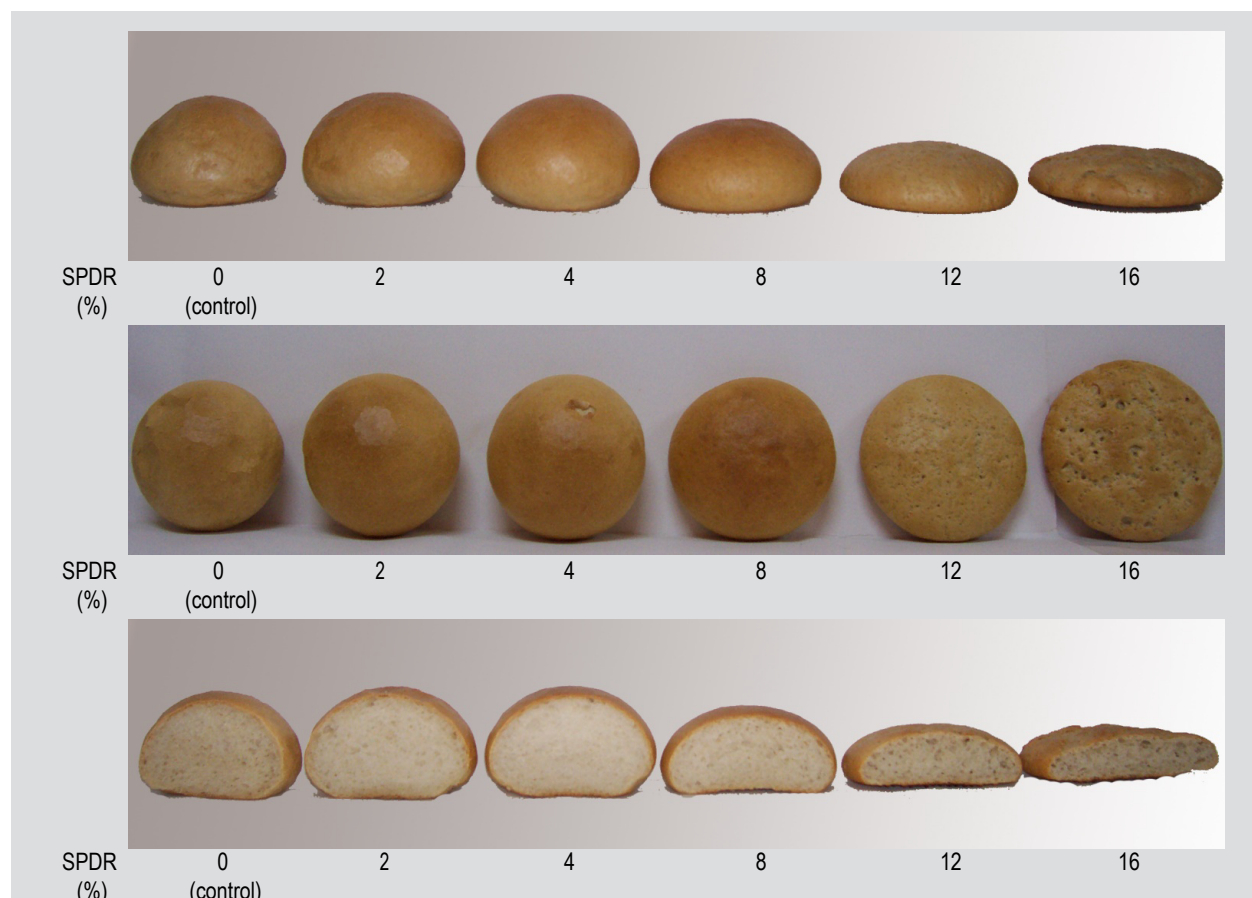


Figure 4. Overall and vertical cross-sectional view of bread samples produced with different sunn pest damage ratios (SPDR) Golia flour with additives.

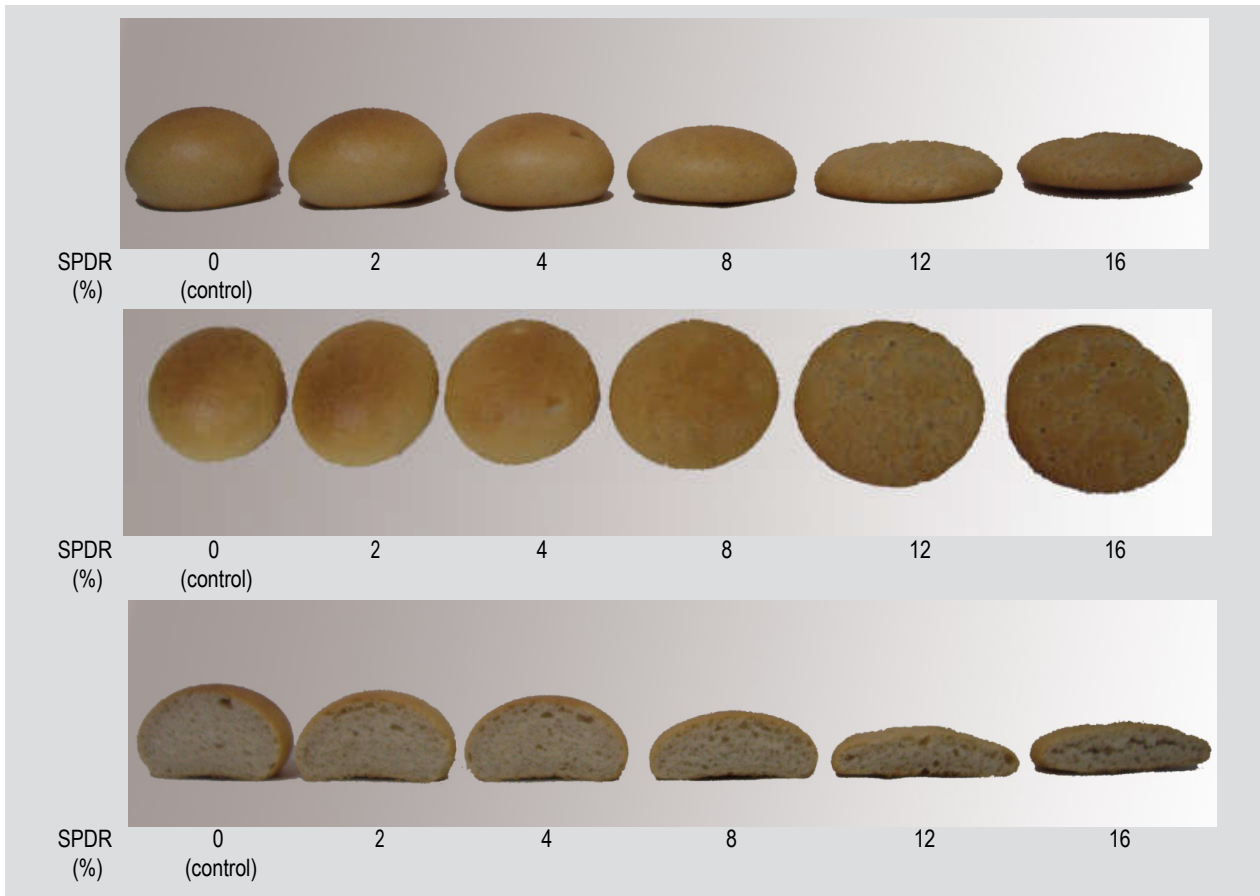


Figure 5. Overall and vertical cross-sectional view of bread samples produced with different sunn pest damage ratios (SPDR) Sagittario flour with additives.

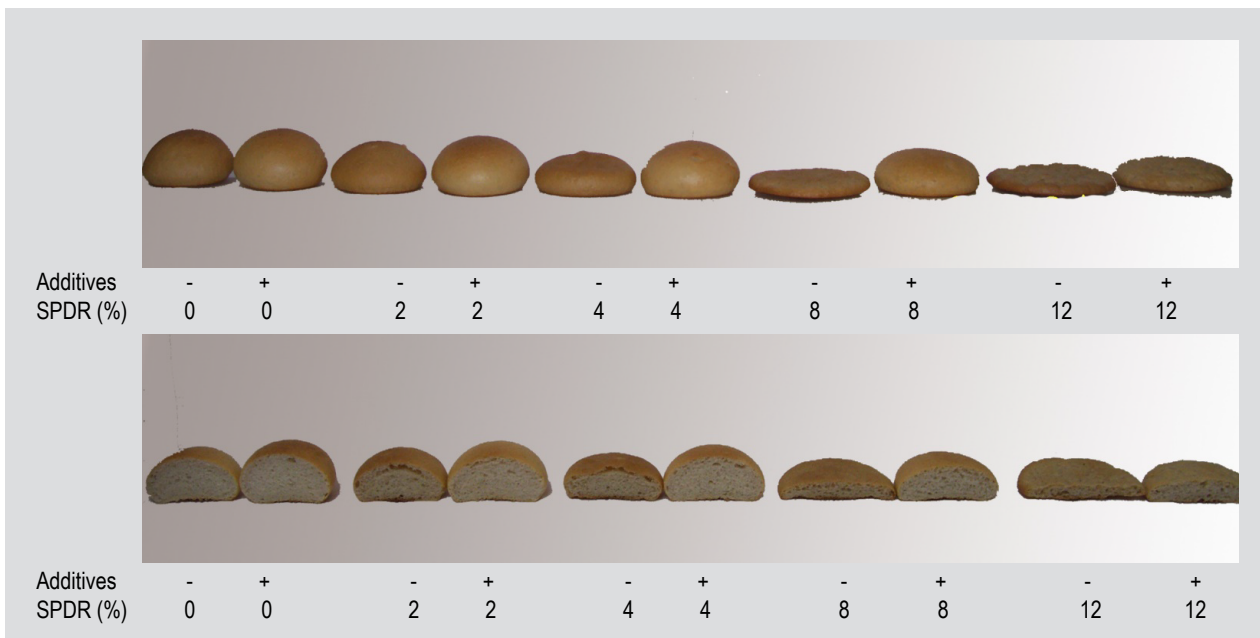


Figure 6. Overall and vertical cross-sectional view of bread samples produced with different sunn pest damage ratios (SPDR) Sagittario flour with and without additives.

yield, specific volume, and penetrometer values of bread produced with 2% SPDR (both varieties) and 4% SPDR (only Golia) were higher than those of the control group (Table 3). This also indicated that the combination of additives used in the study was excessive for the control sample.

Among the bread samples produced using additives, the quality of the bread was desirable with 2% SPDR for Sagittario, as well as with 4% SPDR for Golia. Low quality consumable bread was produced with 8% SPDR for Golia and 4% SPDR for Sagittario. Bread with higher percentages SPDR produced bread of unacceptable quality (Table 3). The bread quality produced with $\geq 8\%$ SPDR can be improved when higher doses of additives, particularly TG, are used. However, the use of more additives also raises the cost of bread production, making it uneconomical to use these levels of SPDR.

The height of the bread samples increased between 5.5 and 95.3% with help of additives. It was found that these increments advanced linearly with the increase in SPDR. In Sagittario additive-free bread, the difference between control and 12% SPDR was approximately 42.5 mm (3.5 times) for the height of bread (Table 1). Using additives, the difference between these groups became approximately 30 mm (Table 3). For the Golia and Sagittario 16% SPDR groups the difference with the control was nearly 34 mm when using additives. For both wheat varieties, crumb-pore structure and penetrometer values of bread decreased very sharply ($P < 0.05$) when the level of SPDR was increased.

In general, similar situations were observed in trials with and without additives: increasing SPDR decreases bread quality, except for 2% SPDR (Sagittario) and 2-4% SPDR (Golia) when additives are used. Moreover, the increase of SPDR in wheat bulk resulted in a reduced quality loss for the additive bread compared to additive-free bread (Tables 1-4). Our results were consistent with the findings in the literature (Atli *et al.*, 1988a; Dizlek and Özer, 2016a; Every, 1991; Every *et al.*, 1989, 1998; Hariri *et al.*, 2000; ICARDA, 1983; Karababa and Ozan, 1998; Matsoukas and Morrison, 1990; Meredith, 1970).

In general, the subjective evaluation of dough samples with and without additives showed similar trends, however, the SPDR threshold value of the dough was increased when additives were added (Tables 2 and 4). Dough characteristics were improved and the dough became easy to process when additives were included in the dough formula. Although this evaluation was subjective, clear differences were found between the dough characteristics that could be attributed to the level of SPDR.

In terms of bread yield, weight loss, height, width, crumb-pore structure, and crumb softness properties, similar results were found for both Golia and Sagittario varieties;

baking quality was negatively ($P < 0.05$) affected by SP damage. However, there was variation in flour qualities due to genetic differences between the varieties. The relatively low quality Sagittario variety was excessively more affected by SP damage than the relatively high quality Golia variety. In both bread making trials, 2% and 4% SPDR Golia groups produced the best bread in terms of volume and softness, as SP damage causes the dough to spread. Thus, the tight crumb structure of the control groups became looser structure for 2% and 4% SPDR groups (Tables 1 and 3).

The study of Every *et al.* (1998) compared the effects of bug proteinase on baking of bug-damaged flour of different cultivars compared to control flours. They concluded that, the classic characteristics of bug-damaged loaves occurred mostly in the poor bread baking cultivars. Our findings were in accordance with Cressey *et al.* (1987), Diraman (2009), Dizlek and Islamoglu (2009), Dizlek *et al.* (2008), 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, 2002, 2003).

One should be very careful about amount of SPDR in wheat mass used for bread making. A too high SPDR may cause the production of very low quality bread, or bread cannot even be produced. Similarly, Hariri *et al.* (2000) reported that two-layered flat bread baking quality was rather tolerant of small amounts of damaged kernels, but addition of 10% or more had a significant effect on bread quality, and the presence of 20% damaged kernels made it impossible to produce satisfactory two-layered flat bread. Dough-handling properties were also affected to the extent that the dough could not be moulded or sheeted, and bread burned during the short (45 s) baking time. They determined that the commercial-type baking procedure was tolerant of wheat containing up to 5% damaged kernels; this also agreed with results obtained by Karababa and Ozan (1998).

It has been reported that the effects of SP damage could relatively be reduced by using additives at specific ratios during the bread making process (Caballero *et al.*, 2005; Köksel *et al.*, 2001; Satouf *et al.*, 1999; Tuncer *et al.*, 2002; Unal *et al.*, 1993). When SPDR was higher than a certain level (depending on the quality of the wheat), the improvement of the baking qualities was impossible. Baking quality could only be regained in wheat damaged by SP to a limited extent by blending with sound wheat or using additives (General Directorate of Agricultural Research and Policies, 2004). Kinaci and Kinaci (2004) showed that the damage caused by SP pierced grain affects the quality of wheat depending on the variety and grain type. As expected, using additives in bread making improved the all bread quality characteristics, particularly volume yield, specific volume, and penetrometer values. Our findings were consistent with the other conducted studies.

In this study, additives with a fixed combination were used in each SPDR in order to compare bread qualitatively. The fixed additive combination improved the quality more of high SPDR bread than low SPDR bread, as expected. Therefore, in bread production using less additives with low SPDR (0-4%) and more additives with high SPDR (>5%) could enable the production of more qualified bread.

4. Conclusions

The aim of this study was to determine the effects of SPDR on baking quality of two bread wheat varieties. The results clearly demonstrated that the ratio of damage by SP in wheat bulk played an important role in bread baking characteristics of both wheat varieties. The increase in SPDR in wheat bulk caused a significant ($P<0.05$) decrease in baking characteristics. When SPDR in wheat bulk increased, weight loss and wideness of bread increased, and bread yield, height of bread (volume expansion), crumb-pore structure and softness of bread samples declined, however the rate of increase or decline depended on the variety.

The decrease in bread quality characteristics started from 2% SPDR and bread properties reduced significantly after 4%. Bread produced up to 4% SPDR could be acceptable, but higher SPDR in wheat bulk produces bread unacceptable for consumption. Bread could not be produced when the SPDR in wheat bulk was increased to $\geq 16\%$. The use of additives, in appropriate composition and level, provide significant improvements to the bread baking characteristics, particularly volume yield, specific volume, and penetrometer values. However, using additives in bread production only compensates the negative effect of SP damage to some extent. It cannot create an absolute solution, as the bread quality at high SPDR – although considerably improved – remains insufficient or becomes uneconomical due to high costs of additives.

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