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The improvement of bread characteristics of sunn pest (*Eurygaster integriceps*) damaged bread wheat by blending application and using additives

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RESEARCH ARTICLE

Abstract

In this study, a wheat variety (Sagittario) exposed to a high level (20.6%) of sunn pest (SP) damage was blended with its undamaged and good quality counterparts at varying levels (100%+0%, 90%+10%, 80%+20%, 70%+30%, 60%+40%, 50%+50%, and 0%+100%). The purpose of this study was to improve the baking quality of sunn pest damaged wheat (SPDW) by blending and using different additives (diacetyl tartaric acid esters of mono and diglycerides, transglutaminase, citric and L-ascorbic acid). Utilising the damaged wheat in bread making and the economic contribution to the economy was determined by optimum blending ratios. The effects of blending applications on the important bread characteristics (bread and volume yield, weight loss, height, width, height/width, specific volume, crumb-grain structure, and penetrometer values) were investigated. When SPDW was mixed with sound wheat, the harm of SP relatively decreased. As SPDW portion in the mixture increased, bread characteristics declined (P<0.05) as expected. Using a high portion of SPDW in the blend should be avoided since a wheat sample that has a good-medium bread quality could lose its functionalities upon the inclusion of high amount of SPDW. At this research scale, the optimum blending ratio was found to be 90%+10% for bread produced without additives and both 90%+10% and 80%+20% for bread produced using additives. As expected, using additives in bread making improved all the bread quality characteristics measured, particularly grain structure and penetrometer values. The application of wheat blending was found to be insufficient to improve the bread quality of wheat samples with a high amount of SP damage. Including additives in bread making made better quality bread production possible.

Keywords: additives, blending, bread quality, sound wheat, sunn pest damaged wheat

1. Introduction

Wheat flour is one of the most important components in bread making not only for quantitative but also for qualitative purposes. In bread production, wheat flour contributes three main functions: protein quantity and quality, amylase activity, and water holding capacity; of these protein quantity and quality are critical in determining the functional properties of wheat flour. Within wheat proteins, gluten proteins (glutenin and gliadin) have specific and very important roles (Dizlek *et al.*, 2006; Dizlek and Özer, 2016) and they mainly determine baking quality of the wheat flour.

Certain species of sap-sucking insects (*Eurygaster integriceps*, *Aelia* spp., *Nysius huttoni*, *Chlorochroa sayi*, and *Stodiplosis mosellana*, etc.) feeding on wheat may harm the grain in different countries (Dizlek and İslamoğlu, 2015). In Turkey, the sunn pest (SP; *E. integriceps* Put., Hemiptera: Scutelleridae) and wheat stinkbugs (*Aelia* spp., Heteroptera: Pentatomidae) are the most important insects associated with cereals (especially wheat) and cause serious damage almost every year (Lodos, 1982). SP attacks developing wheat kernels and the infested grain contains a protease that breaks down the gluten structure of dough (Sivri *et al.*, 1998, 1999). The dough prepared from bug damaged wheat flour is runny and sticky and produces poor quality bread (Aja *et al.*, 2004; Dıraman *et al.*, 2013; Every, 1992; Hariri *et al.*, 2000; Kınacı and Kınacı, 2004; Kretovich, 1944). There is great difficulty in making bread from sunn pest damaged wheat (SPDW) flour (Dizlek and Gül, 2007). Rheological and baking studies have shown that wheat containing >5% bug damaged kernels is unacceptable for producing good quality bread (Karababa and Ozan, 1998).

There have been various studies on the improvement in quality of SPDW and wheat flours (Dizlek and Gül, 2007). For such purposes the principal treatment are heat and hydrothermal treatments prior to milling, such as by tempering with hot water or steam (Dıraman and Atlı, 2005; Dıraman and Demirci, 1997; Ertugay *et al.*, 1995; Olcott *et al.*, 1943), spreading wheat flour at sunlight in order to obtain an effect from ultraviolet rays (Swallow and Every, 1991), the application of low dosage radiation and short time microwave to tempered SPDW (Dıraman, 2010; Sivri and Köksel, 1996; Türker and Elgün, 1998), blending with sound and strong wheat samples (Atlı *et al.*, 1988a; Dıraman and Boyacıoğlu, 1997; Elgün *et al.*, 1992; Özkaya and Özkaya, 1993; Staudt, 1940). In addition, usage of some inhibitors (e.g. sodium chloride up to 3% weight of flour, calcium chloride, potassium bihydrogen phosphate, sodium salicylate) may inactivate protease activity in the dough (Dıraman and Demirci, 1997; Elgün *et al.*, 1992; Olcott *et al.*, 1943), and/or usage of some bread additives (e.g. vital gluten, potassium bromate, L-ascorbic acid (L-AA), transglutaminase (TG), diacetyl tartaric acid esters of mono and diglycerides (DATEM), glucose oxidase, hexose oxidase) to increase the functionality of the gluten during dough preparing stage (Alfin *et al.*, 1999; Atlı *et al.*, 1988a; Bonet *et al.*, 2005; Caballero *et al.*, 2005a,b; Dizlek *et al.*, 2008; Elgün *et al.*, 1992; Köksel *et al.*, 2001; Özkaya *et al.*, 1990; Satouf *et al.*, 1999; Tuncer *et al.*, 2002; Ünal *et al.*, 1993), applications of short processing times, changing pH, water activity, temperature and dough consistency (bread making by emergency method, short fermentation time application, adding organic acid, using sour dough, using of water which adjusting pH, dough making with tough consistency, dough processing at low temperature) to limit the activity of protease (Dıraman *et al.*, 1998; Dizlek, 2010; Elgün *et al.*, 1992; ICARDA, 1983; Matsoukas and Morrison, 1990; Tuncer *et al.*, 2002).

In general, millers are required to apply a blending process, an important step of milling technology, by mixing the wheat varieties with different qualities in order to produce the flour at the quality that is desired by the bakers at the appropriate standard. Blended wheat varieties deliver superior features and have been widely used by millers in many countries (Koçak *et al.*, 1993). Different researchers (Hatcher *et al.*, 2008; Hook, 1983; Koçak, 1988; Türker and Elgün, 1997) working on the blending issue have revealed that it is a process which has positive impacts in the milling and cereal industries as long as it is carried out properly and carefully.

In this study, the aimed was to improve the baking quality of bug damaged wheat sample at a very high ratio (20.6%, being at a quality that can be used as animal feed) by blending and using additives (DATEM, TG, citric acid (CA), and L-AA) in bread making to permit the use of damaged wheat for economic reasons. Additionally, the present study set out to determine the optimum blending ratios in terms of bread quality and give practical information to millers and bakers. Therefore, seven different wheat groups were formed: 100% sound + 0% SPDW (control); 90% sound + 10% SPDW; 80% sound + 20% SPDW; 70% sound + 30% SPDW; 60% sound + 40% SPDW; 50% sound + 50% SPDW; and 0% sound + 100% SPDW. We evaluated the bread characteristics of these blended wheat groups.

2. Materials and methods

Materials

Two samples (SP damage ratio 20.6% and undamaged (sound)) belonging to the same variety (Sagittario) were used in this study. Insect damaged and undamaged wheat samples were purchased from Koca Agricultural Products (Salbaş-Karaisalı, Adana, Turkey) and Savrunlar Milling Factory (Adana, Turkey), respectively. In total 100 SP samples were collected from damaged wheat bulk samples and their varieties were determined at the Agricultural Protection Research Institute (Adana, Turkey) which specialises in the identification of insect species. According to the data, it was determined that 99% of the insects were *E. integriceps* and 1% was *Eurygaster maura.*

TG (TG Activa WM, 100 U/g) was kindly provided by Ajinomoto Co., Inc. (Tokyo, Japan), L-AA (food grade, ELCO C-100 K) and CA (EMCEtric AP) from Mühlenchemie GmbH & Co. KG (Ahrensburg, Germany), DATEM (SAFMILL T-310) and bread yeast were obtained from LeSaffree-Özmaya Co. (Adana, Turkey). Salt was purchased from a local shop. Potable water was supplied within the campus of Çukurova University (Adana, Turkey).

The dough was prepared in an electric kneading machine with a spiral spindle (160 rpm; Günsa Machine, İzmir, Turkey). The fermentation procedures were 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).

Methods

Preparation of blending (wheat and flour) groups

For the determination of the ratio of bug damaged kernels of two wheat samples, 10 sets of 100 kernels were separated randomly from the each sample. The number of SP damaged kernels in each set was recorded and % damage ratio was reported as the average of ten measurements (Atlı *et al.*, 1988a). The Sagittario variety of two samples had SP damage ratios of 0% and 20.6%. Experimental materials were manually prepared as follows: sound and SPDW samples were blended at different levels (100%+0%, 90%+10%, 80%+20%, 70%+30%, 60%+40%, 50%+50%, and 0%+100%). Seven new wheat groups were formed according to their blending ratios. Then, each wheat group was mixed thoroughly so that it was homogeneous within itself. After that, the blended wheat samples were conditioned to 16.5% moisture content for 32 h and milled with a laboratory type mill ('Yücebaş' brand, 'YM1' model tempered wheat grinding mill, including six rolls; Yücebaş Machine, İzmir, Turkey) separately. Finally, the newly milled flour samples were rested for one month at 20 °C for the maturing and then used in bread making experiments.

Dough preparation and bread making studies

Some preliminary experiments were performed during the initial phase of the research. These aimed to determine the appropriate values and practices for some basic procedures to be applied during the main experiments. Kneading, fermentation and baking periods as well as fermentation and baking temperatures and times applied in the research were determined as a result of the preliminary experiments.

In this study, for each blending ratio, a dough formula was prepared separately in two different ways; either including fundamental dough ingredients (flour, water, yeast, and salt) or with constant amounts of additives (DATEM, TG, CA, and L-AA). In bread formula with additives; DATEM at 0.5%, TG at 0.15%, CA at 100 mg/kg, and L-AA at 75 mg/kg were used as constant amounts of additives as flour basis.

The baking formula used was as follows: flour 100%, water (59.4-61.6%), yeast 3%, salt 2%, DATEM 0.5%, TG 0.15%, CA 100 mg/kg, and L-AA 75 mg/kg (these dough ingredients were expressed as percentage of base flour weight). The amount of water in each formula was determined by the farinograms (AACCI approved method 54-21.02; AACCI, 2000). Farinograph water absorption values of flour samples produced from various levels blending ratio of sound and SPDW samples were as follows: 61.1% – 100%+0%; 61.2% – 90%+10%; 60.8% – 80%+20%; 60.2% –70%+30%; 60.0% – 60%+40%; 59.4% – 50%+50%; and 61.6% – 0%+100%. Bread making experiments with 14 different formulations were carried out in triplicates (Table 1).

Bread was made according to the AACCI approved method 10-10.03 (AACCI, 2000) with some modifications. Dough was optimally mixed (16 min with 160 rpm) until developed, scaled into pieces of 100 g weight, hand-rounded, moulded and rested (fermentation) at 25±1 °C and 65-70% relative humidity for 120 min. Baking was carried out in an oven for 16 min at 260 °C. Samples were then cooled for 1 h at room temperature, put into plastic bags and stored at 25 °C until bread analyses were conducted.

Dough samples were not subjected to two separated fermentations as initial and final fermentations, only a single fermentation for 120 min was applied.

Bread analysis

The volume of bread was measured by rapeseed displacement method as cm^3 (AACCI method 10-05.01; AACCI, 2000). The weight of bread samples was determined using a scale and the specific volume of individual bread was calculated from the ratio between volume and weight of the bread. 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). For the purpose of determining the volume yield of bread samples; bread volume, the dough formula, flour content in the formula, and moisture content of flour were taken into consideration, and the calculation was made by proportion. Similarly, the weight of bread produced with 100 g flour based on a moisture content of 14% was calculated as the bread yield. In identifying the bread yield of samples; baked bread weight (after 6 h from baking), the dough formula, flour content in the formula, and moisture content of flour were considered for proportional calculation. Weight loss of bread as an index of moisture loss was measured (Dizlek, 2015) by determining the initial weight of the dough (100 g) as well as the weight of baked bread 6 h cooling after removal from the oven (W1). The weight loss upon baking was calculated as follows:

Table 1. Experimental design of the study.[1]

Sound Sagittario wheat (%)	20.6% SP damaged Sagittario wheat (%)	Additives	
		–	+
100 (control)	0	x	x
90	10	x	x
80	20	x	x
70	30	x	x
60	40	x	x
50	50	x	x
0	100	could not be produced	

[1]Dough prepared separately in two different ways (with and without additives) for each blending ratio formula. The dough formula containing additives and no additives were constant and consisted of the following components: with additives = 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid; without additive = 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt.

Weight loss (%) = (100 – W1) (1)

The height and width of bread samples were determined by a digital calliper. Height/width values were calculated according to Hoseney (1986) with the partial modification of spread ratio test. Crumb-grain structure was evaluated visually and judged according to the Dallman scale 1-8 with higher scale numbers indicating smaller pores and more dense structure in bread (TSE, 1987). A SUR penetrometer PNR 6 (SUR, Berlin, Germany) with 200 g of total test weight was used to determine the crumb firmness (penetrometer values) of the finished product as indicated by Özer and Altan (1995). Crumb firmness was measured within 6 and 24 h after removal from the oven, and other analyses were conducted within 6 h after the bread was removed from the oven.

Statistical analysis

All experiments were carried out in three replicates. Analyses of variance (ANOVA) was conducted by using the Statistical Analysis System procedures (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 ($P<0.05$). Bread produced without additive and constant amounts of additives were subjected to statistical analyses separately.

3. Results and discussion

Bread produced without additives

The effects of various levels of blending sound wheat and SPDW samples on the quality characteristics of bread containing no additives are given in Table 2 and 3. Overall and vertical cross-sectional views of the bread samples produced without additives are presented in Figure 1 and 2. As can be seen from Table 2, based on the increase in the amount of the sound wheat mass in the blend, while the yield, swelling (height) and height/width values of the bread increased, the values of the weight loss and the wideness decreased ($P<0.05$). The bread yield and the height values with the blending with a ratio of 50%+50% were less than those of the bread made without SP damaged (100%+0%) at about 10% and 60%. The values for weight loss and width for the same groups were about 53 and 30%, respectively. The width of the bread increased in accordance with the increase of SPDW in the blend. This increase was more in the 50%+50% blending group with a ratio of 62%, than in control group.

With an increase of sound wheat in the blend; volume yield, specific volume, grain structure and penetrometer values increased ($P<0.05$), and the most dramatic improvement occurred in the crumb grain structure. With the 50%+50% blending ratio, the penetrometer value of bread samples could not be measured because of the thickness (height) of the bread slices was less than 28 mm (Figure 1, 2 and Table 3). With the 0%+100% blend, bread could not be produced due to the intensive SP damage (20.6%). So, measurements of this group could not be taken (Table 2 and 3).

From the bread samples which were produced using the only basic dough ingredients (flour + water + yeast + salt), it was concluded that the bread produced at the blending ratio of minimum 80%+20% could be acceptable, but the quality of the bread significantly declined and was unacceptable when the group had 30% and higher levels SPDW ratio.

In subjective evaluations (observations not shown) made just after kneading and fermentation of dough, it was observed that the form of dough was spherical like a ball

Table 2. The effects of various levels blending of sound wheat and sunn pest damaged wheat samples on some characteristics of bread produced without additives.[1,2]

Blending ratio[3]	Bread yield (g/100 g flour)	Weight loss (%)	Height value (mm)	Width value (mm)	Height/width value
100%+0%	143.5^a	13.6^d	54.3^a	95.4^e	0.57^a
90%+10%	143.2^a	13.8^d	45.3^b	102.4^d	0.44^b
80%+20%	137.3^b	17.2^c	41.1^c	108.4^c	0.38^c
70%+30%	135.5^c	18.0^b	30.7^d	117.4^b	0.26^d
60%+40%	135.2^c	18.1^b	30.0^d	117.2^b	0.26^d
50%+50%	130.0^d	20.9^a	22.5^e	124.5^a	0.18^e

[1] The separately prepared dough formula for each of the blending rate was constant and consists of following components: 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt.

[2] Mean values in the table for the same column shown with the different superscript letter are significantly different ($P<0.05$).

[3] First value of the blending ratio represents the wheat sample not damaged (sound) by sunn pest, and the second represents 20.6% damaged sample in the blending portion.

Table 3. The effects of various levels blending of sound wheat and sunn pest damaged wheat samples on volume yield, specific volume, grain structure, and penetrometer values of bread produced without additives.[1,2]

Blending ratio[3]	Volume yield (cm^3/100 g flour)	Specific volume (cm^3/g)	Crumb-grain structure (0-8 score)	Penetrometer values (1/10 mm)	
				6th h	24th h
100%-0%	564[a]	3.93[b]	5.7[a]	77[a]	54[a]
90%-10%	558[a]	3.90[b]	4.8[b]	64[b]	46[b]
80%-20%	548[b]	3.99[a]	4.3[bc]	58[b]	41[c]
70%-30%	517[c]	3.82[c]	3.7[c]	46[c]	30[d]
60%-40%	464[d]	3.43[d]	2.2[d]	40[c]	27[e]
50%-50%	408[e]	3.13[e]	1.5[d]	–[4]	–[4]

[1] The separately prepared dough formula for each of the blending rate was constant and consists of following components: 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt.

[2] Mean values in the table for the same column shown with the different superscript letter are significantly different (P<0.05).

[3] First value of the blending ratio represents the wheat sample not damaged (sound) by sunn pest, and the second represents 20.6% damaged sample in the blending portion.

[4] Could not be measured because of the thickness (height) of the bread slices less than 28 mm.

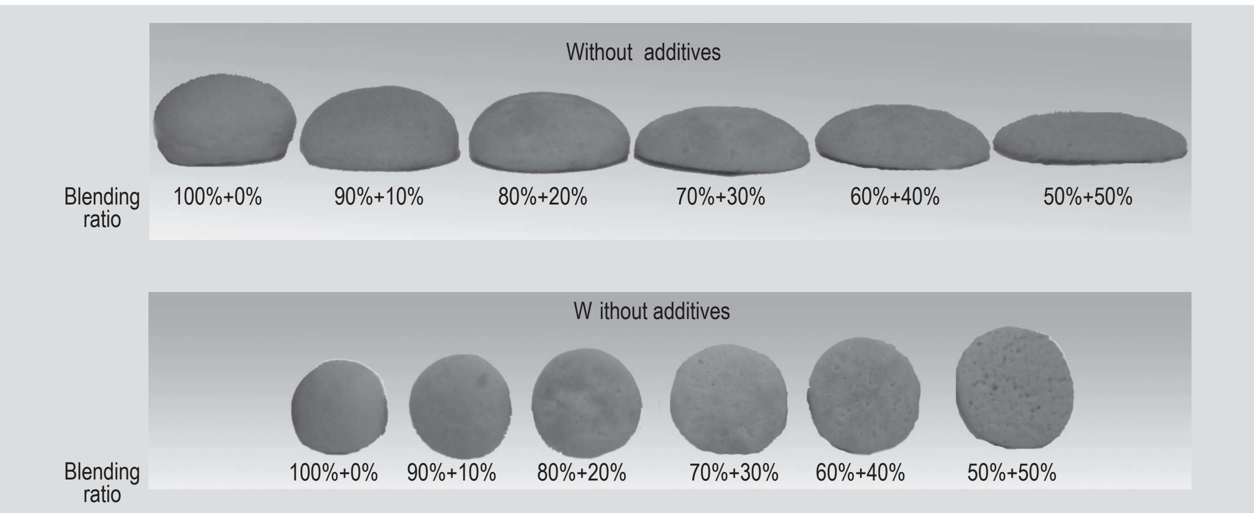

Figure 1. The effect of various levels blending of sound wheat and sunn pest (SP) damaged wheat samples on view of the bread samples (without additives: 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt). First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

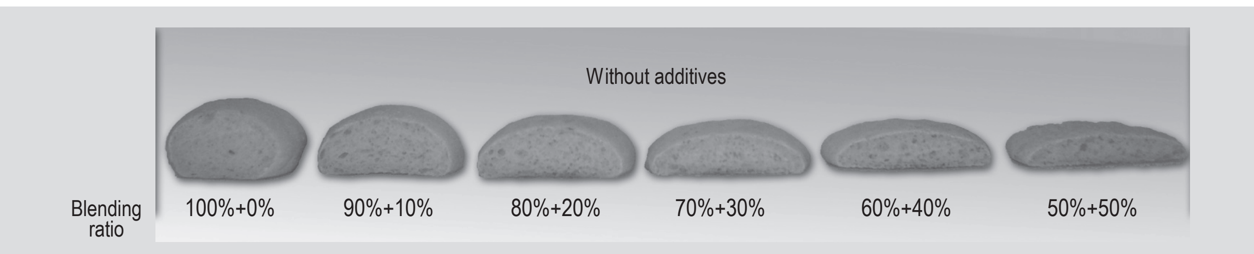

Figure 2. The effect of various levels blending of sound wheat and sunn pest (SP) damaged wheat samples on vertically cross-sectional view of the bread samples (without additives: 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt). First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

in the control sample and 90%+10% blend. Dough had a splayed and soft form with increases in the SPDW sample in the blend. When the SPDW ratio was 30%, the dough had a very excessive splayed and adhesive character.

Bread produced with constant amount additives

The effects of various levels blends of sound wheat and SPDW samples on the quality characteristics of bread containing additives are given in Table 4 and 5. Overall and vertical cross-sectional views of the bread samples produced with additives are presented in Figure 3 and 4; with and without additives are presented in Figure 5 and 6.

By examining the Tables 4 and 5 together, it has been determined that when the percentage of SPDW mass in the blend increased to 20% it affected bread qualities to a very limited degree, but negative effects were more evident at 30% level and very obvious ($P<0.05$) at the 40 and 50% levels. The use of additives improved the dough (subjective evaluations not shown) and bread characteristics (Table 2-5). It was observed that using the additives with 100% sound Sagittario seemed to produce an unsuitable dough with cleaving and cracking of the bread. As for the bread trials produced with additives, it was found that volume yield, specific volume, and penetrometer values of bread produced with the blending ratio of 90%+10% were higher than the control group had (Table 5). This is another

Table 4. The effects of various levels blending of sound wheat and sunn pest damaged wheat samples on some characteristics of bread produced with additives.[1,2]

Blending ratio[3]	Bread yield (g/100 g flour)	Weight loss (%)	Height value (mm)	Width value (mm)	Height/width value
100%+0%	144.6^{a}	13.3^{e}	58.9^{a}	93.6^{e}	0.63^{a}
90%+10%	143.9^{ab}	13.7^{de}	57.9^{a}	97.4^{c}	0.59^{b}
80%+20%	143.4^{b}	13.9^{d}	53.3^{b}	96.0^{d}	0.56^{c}
70%+30%	140.9^{c}	15.1^{c}	50.0^{c}	97.0^{cd}	0.52^{d}
60%+40%	136.9^{d}	17.3^{b}	37.3^{d}	106.6^{b}	0.35^{e}
50%+50%	134.2^{e}	18.7^{a}	31.0^{e}	112.5^{a}	0.28^{f}

[1] The separately prepared dough formula for each of the blending rate was constant and consists of following components: 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid.
[2] Mean values in the table for the same column shown with the different superscript letter are significantly different ($P<0.05$).
[3] First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

Table 5. The effects of various levels blending of sound wheat and sunn pest (SP) damaged wheat samples on volume yield, specific volume, grain structure, and penetrometer values of bread produced with additives.[1,2]

Blending ratio[3]	Volume yield (cm^3/100 g flour)	Specific volume (cm^3/g)	Crumb-grain structure (0-8 score)	Penetrometer values (1/10 mm)	
				6th h	24th h
100%+0%	582^{b}	4.02^{b}	7.0^{a}	99^{a}	80^{a}
90%+10%	606^{a}	4.21^{a}	6.2^{bc}	104^{a}	83^{a}
80%+20%	577^{b}	4.03^{b}	6.3^{ab}	88^{b}	70^{b}
70%+30%	556^{c}	3.95^{c}	5.5^{c}	81^{b}	63^{c}
60%+40%	529^{d}	3.86^{d}	3.2^{d}	53^{c}	38^{d}
50%+50%	506^{e}	3.77^{e}	2.5^{d}	42^{d}	31^{e}

[1] The separately prepared dough formula for each of the blending rate was constant and consists of following components: 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid.
[2] Mean values in the table for the same column shown with the different superscript letter are significantly different ($P<0.05$).
[3] First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

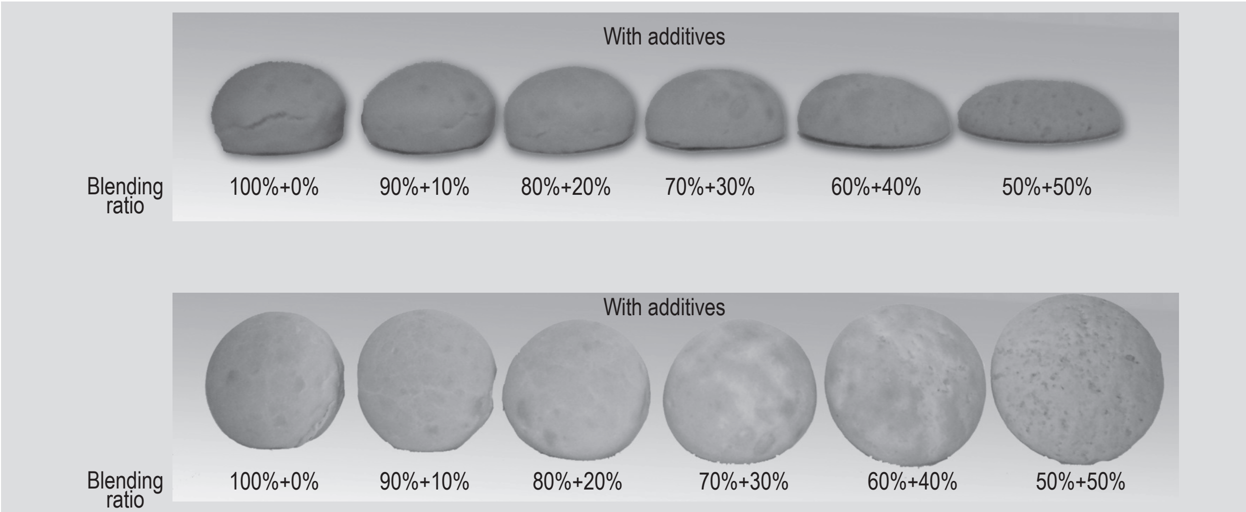

Figure 3. The effect of various levels blending of sound wheat and sunn pest damaged wheat samples on view of the bread samples (with additives; 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid. First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

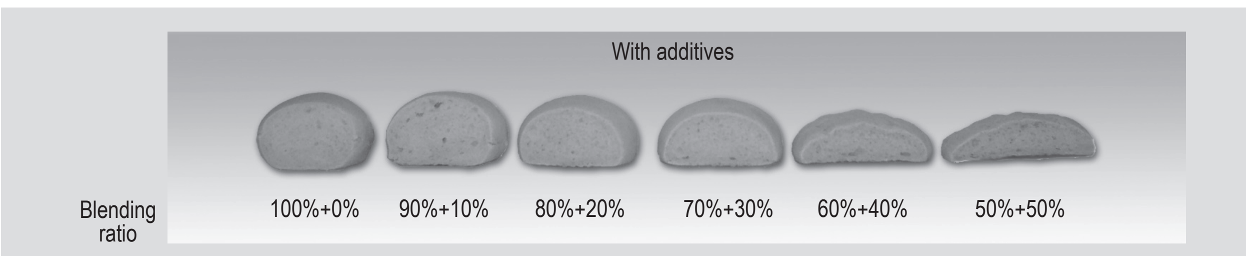

Figure 4. The effect of various levels blending of sound wheat and sunn pest damaged wheat samples on vertically cross-sectional view of the bread samples (with additives; 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid). First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

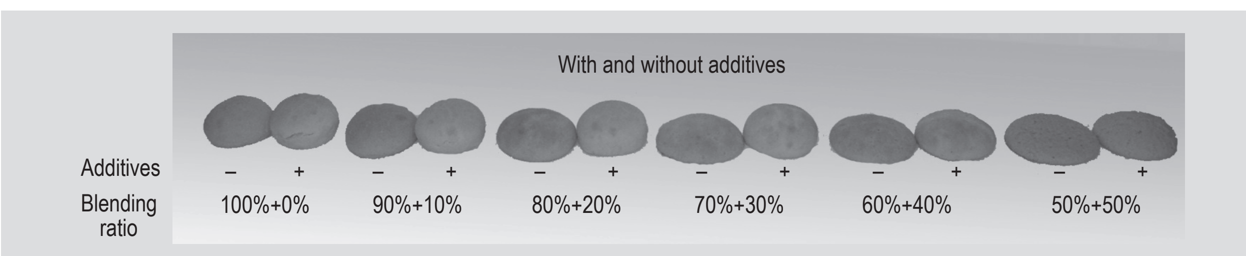

Figure 5. The effect of various levels blending of sound wheat and sunn pest damaged wheat samples on view of the bread samples (without and with additives; 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid). First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

case showing that the combination of the additives used in the study seemed to be excessive with the control sample.

In this study, the additives were used in a fixed combination with each of the blends in the trials. The fixed additive combination improved the quality of the bread samples with

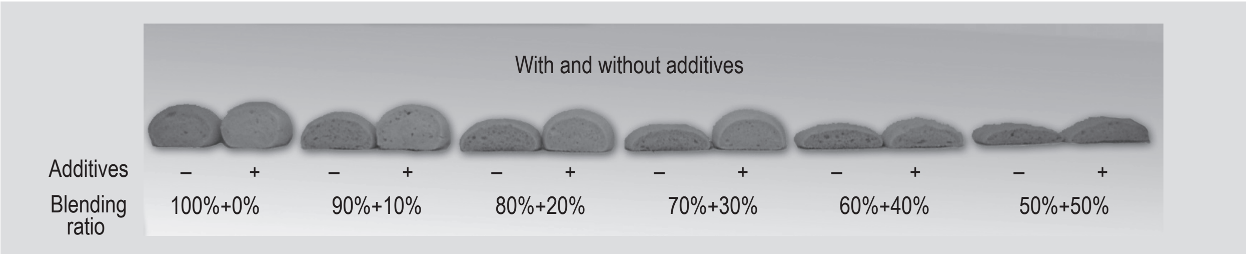

Figure 6. The effect of various levels blending of sound wheat and sunn pest damaged wheat samples on vertically cross-sectional view of the bread samples (without and with additives; 100 g flour + water (farinograph water absorption value) + 3 g yeast + 2 g salt + 0.5 g diacetyl tartaric acid esters of mono and diglycerides + 0.15 g transglutaminase + 0.01 g citric acid + 0.0075 g L-ascorbic acid). First value of the blending ratio represents the wheat sample not damaged (sound) by SP, and the second represents 20.6% damaged sample in the blending portion.

more SPDW mass than the less SPDW mass in blending, as expected. Hence, using less additives in blending with less SPDW mass (0-10%) and more additives in blending with more SPDW mass (40-50%) can enable the production of more qualified bread.

Among the bread samples which were produced using additives with constant quantities of DATEM, TG, CA, and L-AA in addition to fundamental dough ingredients, the quality of the bread can be said to be acceptable with a blending ratio of a minimum of 70%+30%. The lowest quality acceptable bread was produced with an addition of SPDW to a maximum 40%. When the two wheat samples were used together with equal ratios, the bread quality was unacceptable (Table 4 and 5). The quality of the bread produced with this blend can be improved using additives with higher doses (particularly TG), but using more additives increases the cost of the bread.

In general, similar situations were observed in trials of additive and additive-free bread. The addition of the SPDW to the blend decreased the quality of the bread. Moreover, the decrease in the quality with additives was less than the decrease in additive-free bread (Table 2-5). The findings on the bread properties of wheat were consistent with previous findings (Atlı *et al.*, 1988b; Dizlek and Özer, 2016; Every, 1991; Hariri *et al.*, 2000; ICARDA, 1983; Karababa and Ozan, 1998; Matsoukas and Morrison, 1990; Meredith, 1970).

The use of additives in bread making, when the SPDW mass was high in the blend, further improved the bread quality by contrast with the blended groups including low SPDW. A decline at the bread quality caused by the increase of SPDW mass in the blend in bread with additives was at a lower level than with additive-free bread (Table 2-5).

In subjective evaluations made just after kneading and fermentation of dough, it was observed that the dough samples prepared with and without additives were very similar, however, the threshold value of the SPDW portion in the blend was found to be higher with additives for the deterioration of dough quality (in general, similar situations were observed in trials of additive and additive-free dough samples in terms of sensory evaluation. The increase in the SPDW sample in blending decreased the quality of the dough of the control group both in additive and additive-free dough samples. Moreover, the decrease in the quality of the additive dough was less than the decrease in additive-free dough when linked with an increase of SPDW in the sample).

It is necessary to be very careful with the amount of SPDW mass use in blends. Özkaya and Özkaya (1993) and Staudt (1940) reported that reducing the impact to SPDW cultivar might be achieved by blending by sound and strong wheat. They suggested that there should not be too much SP destruction associated with the wheat to be used for blending, otherwise, the contribution of the sound wheat may be compromised. Dıraman and Boyacıoğlu (1997) investigated the addition of 40% undamaged American hard red winter wheat to a wheat variety with a SP damage ratio of 10% and found that it was not possible to improve the quality of the wheat using blending.

Staudt (1940) reported that with Russian wheat samples affected by the wheat bug, this was not the case, owing to the fact that the incorporation of a percentage of this infected wheat in the blend introduced an abnormally high percentage of proteolytic enzymes, whose destructive effects were very prominent in the flour and dough. The presence of such Russian wheat in the grist affected the blend in two ways: (1) by the poor quality of its gluten; and (2) by its excess of proteolytic enzymes. The unfavourable effect was not confined in the grist to the Russian wheat itself but was transmitted to the other wheat samples in the blend, by virtue of its high protease content.

It has been reported that SP damage could be relatively reduced by mixing (blending) the wheat damaged by SP with the quality wheat (hard, strong, and sound) at the specific ratios (Atlı *et al.*, 1988b; Dıraman *et al.*, 1998; Özkaya and Özkaya, 1993; Ünal *et al.*, 1993). In the current study, similar results were obtained. If it was the case that the SP damage grain ratio was higher than a certain level (which varies depending on the quality of wheat) then improvement of the baking qualities of the flour derived from that wheat was impossible. However, it has been determined that the wheat damaged by SP at a limited level could be regained to the economy by blending with sound wheat (General Directorate of Agricultural Research and Policies, 2004).

Bread could not be produced using the flour of the 20.6% SP-damage ratio group (0%+100%; Table 1) due to the high level of proteolytic enzyme activity (Dizlek and Özer, 2016), which was determined for the purpose (improving bread making quality of the SPDW mass and its economic value) of the blending treatment (Table 2-5 and Figure 1-6). As the sound wheat was added to the SPDW mass, the production of the bread could be achieved and the quality of the bread increased considerably ($P<0.05$), according to the increasing ratio of the sound wheat in the blend. This improvement in bread quality was found to be more obviously related with the use of additives.

In the evaluation of the results obtained in this study, the SPDW used in blending can be said to be more decisive than the sound wheat in determining the quality of the wheat flour and dough. On the other hand, the ratio of the SPDW in the blending was dominant in specifying the quality of the intermediate (flour and dough) and main (bread) products. The low quality wheat had an effect on the high quality wheat and led to deterioration in product quality. In the determination of both wheat samples with their simple features, of the blends even the 90%+10% blend reflected the SPDW characteristics more than sound wheat.

4. Conclusions

This study was conducted to determine the bread characteristics of the blending at different levels of two bread wheat samples (SP damaged kernels ratio 20.6% and undamaged) to improve the baking quality of SPDW sample by blending. For this reason, in order to determine the effect of the ratio of SP damaged and sound wheat in blending more precisely bread was firstly made without additives and then with additives (0.5% DATEM, 0.15% TG, 100 mg/kg CA, and 75 mg/kg L-AA by flour basis).

When SPDW was blended with sound wheat, the harm of SP relatively decreased. Along with the increase of SPDW portion in the blend, bread characteristics of wheat declined ($P<0.05$). It is necessary to be very careful with high levels of SPDW in blending applications. At this research level, it has been concluded that the optimal blending ratios were 90%+10% for bread produced without additives; 90%+10% and 80%+20% for bread produced with additives. As expected, using additives in bread making improved all of the bread quality characteristics, particularly grain structure and penetrometer values. In conclusion, the application of the blending was found to be insufficient alone to improve the bread quality of the wheat samples including high amounts of SP damage as used in this study. Using additives in bread making in addition to the application of the blending with high amounts of SPDW can make more qualified bread production possible.

During the application of wheat blending, each wheat mass used in blending should be well characterised. In addition, it was considered necessary to be useful to take into account factors such as SP damaged grain ratio (%), classification SPDW kernels according to the level of evidence for sucking (1/4, 2/4, 3/4, and 4/4), and the damaging stage of SP. Otherwise, the quality of the sound wheat sample may be compromised in blending application.

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