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The Effect of Suni-Bug (*Eurygaster spp.*) Damaged Wheat on the Physical Properties of Extrusion Cooked Product

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The effects of supplementation of high protease activity wheat (*Triticum aestivum*) flour due to bug (*Eurygaster* spp.) damage on characteristics of wheat flour extrudates were investigated. Different proportions of high protease activity flour (HPAF) were blended with wheat flour (0, 10, 20, 30 and 40%) and extruded with a twin-screw Brabender laboratory extruder (Model CTSE-V) at two different barrel temperatures (140℃ and 160℃). The obtained extrudates were tested for extrusion quality parameters. Significant differences were observed between two barrel temperatures (140℃ and 160℃) in terms of water absorption index (WAI), specific mechanical energy (SME), bulk density (BD) and color (redness) values of the extrudates ($p < 0.05$). Statistical analysis showed that addition of HPAF had significant effect on SME, WAI and WSI (water solubility index) values of extruded samples at 140℃. At higher process temperatures (160℃), SME, color, WAI and WSI values of the extrudates were significantly affected by the addition levels of HPAF. At both process temperatures, a significant decrease and a significant increase were observed in BD and ER (expansion ratio) values of the extrudates, respectively. These results suggested HPAF had positive effects on some quality parameters (BD, ER, WAI and WSI) of the extrudates in the proportions examined.

Keywords: suni-bug, *Eurygaster* spp., bug-damaged wheats, extrusion.

Introduction

High protease activity in wheat due to the pre-harvest attack of insects (*Heteropterous*) has been reported since 1931 in East Europe, North Africa and Middle East countries and New Zealand (Kretovich 1944, Paulian and Popov 1980, Cressey *et al.,* 1987). Before harvest, the insects (*Eurygaster* spp., *Aelia* spp. and *Nysius huttoni*) inject their salivary secretions containing proteases on maturating wheat ears when feeding. Damaged wheat kernels may have similar physical properties (shape, weight, etc.) to normal wheat kernels except for a characteristic puncture mark surrounded by a pale area. Therefore, the damaged kernels cannot be separated during milling and the proteases persist in the flour. The proteases break down the gluten structure during mixing and fermentation resulting in poor rheological properties due to weak gluten strength and inferior bread characteristics (Kretovich, 1944; Lorenz and Meredith, 1988; Every *et al.,* 1998; Sivri *et al.,* 1998; 1999). Flour milled from bug-damaged (*Eurygaster* spp., *Aelia* spp. and *Nysius huttoni*) wheat exhibits weak dough properties and unsatisfactory baking quality due to enzymatic degradation of gluten proteins (Cressey and McStay 1987, Sivri and Köksel 1996, Sivri *et al.,* 1998, 1999, Köksel *et al.,* 2001). Although, the effects of bug protease on gluten proteins and baking properties have been well documented, to the best of our knowledge, no studies have been published on the utilization bug-damaged flour in extrusion cooking.

Extrusion cooking is a high temperature-short time (HTST) process can be an attractive alternative for using bug-damaged wheat flour, which is unsuitable for the baking industry due to its weak gluten properties. In this process, the product is subjected to high temperature, high pressure and severe shear. During extrusion cooking, gluten proteins become an elastic material that easily expands upon release of pressure to form many thin-walled cells. Some results of cooking during the extrusion process are gelatinization of starch, denaturation of proteins, inactivation of many native enzymes, destruction of natural inhibitors (such as trypsin inhibitor in soybean) and mycotoxins (Colonna *et al.,* 1989; Katta *et al.,* 1999; Abd El-Haldy and Habiba, 2003). A few reports in the literature are available on the effects of extrusion cooking on enzyme activity. Early papers suggested nearly complete irreversible inactivation of α-amylase, lipase, lipoxydase, peroxidase and urease (Mustakas, 1964; Gardner *et al.,* 1969; Williams *et al.,* 1977). Linko *et al.* (1984) suggested that wheat of exceptionally poor baking quality due to sprout-damage can be processed into flatbread of excellent quality by extrusion cooking. In this study, the effects of bug-damaged (*Eurygaster* spp.) flour on the physical properties of wheat extrudates were investigated when added at different proportions and two different barrel temperatures.

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Materials and Methods

Sample Preparation A severely bug-damaged (*Eurygaster* spp.) wheat sample (>80% damaged kernels) was obtained from the Turkish Grain Board. The bug damaged wheat sample was milled to straight-grade flour in a Buhler laboratory mill to obtain high protease activity flour (HPAF). A commercial wheat flour (General Mills Bakers flour, Gold Medal, All Purpose, Wheat Flour) was also obtained from a local producer. Moisture and protein contents were determined according to Approved Methods (AACC, 1983). Before extrusion, moisture contents of the flours were adjusted to 18.0% by pulverizing in a fine mist of water in a rotating pan. The tempered flours were stored in plastic containers overnight to allow them to equilibrate. The commercial wheat flour was blended with HPAF at 0% (Control), 10, 20, 30 and 40% levels by using a Hobart mixer (Model C-100, Hobart Co., OH) 1 h before extrusion.

Extrusion Extrusion experiments were performed with a twin-screw Brabender laboratory extruder, (Model CTSE-V, Brabender Instruments, Inc., NJ) with conical corotating screws. The screws had diameters decreasing from 43 mm to 28 mm along their 365 mm length. The screw compression ratio was 3: 1 and the die nozzle diameter was 3 mm. The operation conditions were selected according to the preliminary experiments. Two different extrusion temperatures (140℃ and 160℃) were used and extrusion temperatures were fixed in all zones of the barrel in each experiment. The screw speed was 140 rpm. Extruded material was cooled to room temperature and stored at 20℃ in plastic bags until analysis.

Specific Mechanical Energy Specific mechanical energy (SME) was determined according to the method of Bhattacharya and Choudhury (1994) and calculated using the formula:

$$SME = \Gamma \, \Omega / m$$

SME = specific mechanical energy (J/g),
Γ = torque (Nm),
Ω = angular velocity (1/sn), $\Omega = (2\pi N \text{ (rev/min)}/60)$,
m = mass flow rate (g/s)

Water Absorption Index (WAI) and Water Solubility Index (WSI) The water absorption index (WAI) and water solubility index (WSI) values were determined as described by Anderson *et al.,* (1969). The WAI and WSI values were reported as the average of triplicate determinations.

Expansion Ratio The diameters of extrudates were measured with a micrometer. Radial expansion ratio (ER) of an extrudate was calculated by dividing the average cross-sectional area of the extrudate by the cross-sectional area of the nozzle. Extrudate diameters were reported as the average of ten readings.

Bulk Density Extrudate volume was determined by the replacement medium method using small glass beads (Ali et al., 1996). Bulk density (BD) was expressed as the average of five readings calculated using the formula:

$$Q_e = (W_{ex}/W_{gb})Q_{gb}$$

Q_e = bulk density of extrudate (g/cm^3),
W_{ex} = extrudate weight (g),
W_{gb} = weight of glass beads displaced by extrudate (g),
Q_{gb} = density of the glass beads (g/cm^3).

Color The color of the ground extrudates was measured with a Hunter Lab Color Difference Meter (CR-300 Minolta Chroma Meter, Minolta Camera Co., Ltd., Osaka, Japan) against a standard white plate. The lightness (*L*), redness (*a*), and yellowness (*b*) values were reported as the average of five readings.

Statistical Analysis The effect of HPAF addition was statistically evaluated by one-way analysis of variance (ANOVA) using MSTAT-C statistical software (1988). The least significant difference (LSD) test was applied to compare the mean values. The Student's *t* test was applied to compare the effect of barrel temperatures on physical properties of extrudates using SPSS statistical software ver. 10.0 (1999).

Results and Discussion

The Zeleny sedimentation test and modified sedimentation test values of the heavily bug damaged wheat sample were 17 ml and 5 ml, respectively. The significant difference between the Zeleny sedimentation test and modified sedimentation test values confirmed that the selected sample was severely bug-damaged (Greenaway *et al.,* 1965). Various researchers have reported that wheat containing >5% bug-damaged kernels is unacceptable for producing a good quality bread. Consequently, the damaged wheat sample was not analyzed further to evaluate its baking quality. Protein, fat and dietary fiber contents of the commercial wheat flour (General Mills Bakers flour, Gold Medal, All Purpose, Wheat Flour) were 10.5% (Nx5.7), 1.0 g/100 g and 3.0 g/100 g respectively.

The quality parameters, such as SME, WAI, WSI and *L, a* and *b* of the samples supplemented with HPAF in different proportions (0, 10, 20, 30 and 40%) are presented in Table 1.

Addition of HPAF resulted in significant ($p<0.05$) differences in SME, WAI, WSI, BD and ER values of extrudates at 140℃. However, all quality parameters of the extrudates except *b* and *L* values were significantly ($p<0.05$) affected by the HPAF addition level at 160℃. SME values decreased significantly at 20, 30 and 40% HPAF proportions at 140℃, while the opposite trend was observed in the samples extruded at 160℃.

The effects of the HPAF addition on ER and BD values are presented in Fig 1 and Fig 2, respectively. Statistical analysis showed that ER values of the samples extruded at 140℃ increased significantly ($p<0.05$) with increased addition of HPAF. At 160℃, ER values increased significantly ($p<0.05$), up to the 20% HPAF addition level and there were no significant differences among the ER values at higher HPAF addition levels (30% and 40%). ER values at higher addition levels were comparable to those at the 20% addition level. BD value was associated directly with radial expansion of extruded products (Martinez-Bustos *et al.,* 1998). In the present study, the lowest BD values were found in samples that had the

Table 1. Quality Parameters of Bug-Damaged Flour Added Samples Extruded at Two Different Barrel Temperatures*.

PROCESS TEMPERATURE (°C)	ADDITION LEVEL OF HPAF (%)	SME (J/g)	WAI	WSI	L	a	b
140	0	761 a	6.67 b	23.46 bc	52.25	0.36	4.53
	10	839 a	6.63 b	23.46 bc	51.30	0.44	5.04
	20	596 b	6.69 b	23.04 c	51.95	0.45	5.48
	30	655 b	7.30 a	24.42 b	52.70	0.49	5.03
	40	641 b	7.37 a	27.34 a	52.60	0.50	4.94
	LSD	91.34	0.456	1.245	ns	ns	ns
160	0	512 c	6.06 c	20.52 d	52.63	0.70 b	4.95
	10	560 bc	6.40 b	23.12 c	52.49	0.62 b	5.59
	20	612 ab	6.58 ab	25.31 b	52.76	0.65 b	5.24
	30	629 a	6.69 ab	26.38 b	52.37	0.87 a	6.67
	40	625 a	6.84 a	28.17 a	52.62	0.82 a	4.92
	LSD	52.45	0.329	1.558	2.180	0.124	ns

* Means with in columns followed by the same letter are not significantly different (p>0.05) by least significant difference (LSD) test
Specific mechanical energy (SME), Water Absorption Index (WAI), Water Solubility Index (WSI) Lightness (L), Redness (a) and Yellowness (b)

highest ER values. Similarly, the highest BD values were found in samples that had the lowest ER values at both barrel temperatures. ER is generally accepted as the primary quality parameter in extrusion products associated with product density, crispness, water absorption, water solubility and crunchiness (Ali *et al,* 1996). Duarte *et al.,* (1998) reported that high ER resulted in a crispy texture rather than a crunchy texture.

WAI values ranged from 6.67 to 7.37 and from 6.06 to 6.84 (g water/g dry sample) for extrudates produced at 140℃ and 160℃, respectively. The differences were significant among the HPAF levels ($p < 0.05$). At 140℃, WAI values were comparable up to 30% addition levels, however higher WAI values were obtained after this addition level. HPAF addition resulted in significant increases in WAI values of the extrudates processed at 160℃ ($p < 0.05$). The highest WAI was obtained at the highest HPAF addition level (40%) at this barrel temperature. In the present study, all WAI values were slightly lower than the WAI values (8–11 g water/g dry sample) reported in the literature for wheat starch (Anderson *et al.,* 1969). A direct comparison of WAI in the literature is difficult due to the differences in processing conditions and raw materials used in this study. WAI has been used as a direct estimation of porosity of the material. As WAI values increase, porosity of the extrudates also increases (Colonna *et al.,* 1989). Therefore, it can be concluded that addition of HPAF caused a significant increase in porosity of the extruded samples.

The WSI values for extrudates at the high addition level (40%) were significantly different at 140℃. Although, WSI values increased with an increase in the level of HPAF addition, comparable WSI values were obtained for 20% and 30% addition levels at 160℃.

The results obtained in this study suggested that higher WAI and WSI values are associated with higher ER values and are consistent with previously reported studies. Colonna *et al.,* (1987) reported that WSI is related to the quantity of soluble molecules in the extrudate and increases with expansion. Rayas-Duarte *et al.,* (1998) suggested higher ER values were associated with higher water absorptions. Water absorption has been generally attributed to the dispersion of starch due to gelatinization and extrusion-induced fragmentation. Besides the changes in starch, type of protein and degree of protein denaturation are also reported to affect the WAI (Gujska and Khan 1990).

Although, there were some variations in color values (*L*, *a* and *b*), the changes were not statistically significant for the extrudates processed at 140℃. However, the difference in *a* values of the samples extruded at 160℃ were statistically significant at 30% and 40% addition levels.

The effects of barrel temperatures on the properties of the extrudates were compared using Student's *t* test and presented in Table 2. Statistical analysis showed that barrel temperature had a significant effect on SME, BD, WAI and redness (*a*) values of extruded samples ($p < 0.05$). SME, WAI and BD values were significantly higher ($p < 0.05$), and redness (*a*) values were significantly lower, in the samples extruded at 140℃ when compared to those of sample extruded at 160℃. The viscosity of the product inside the extruder decreases due to higher barrel temperature hence friction between product and barrel surface is lower. This results in decreased SME value (Colonna 1989).

Other quality parameters (ER, *L*, *b* and WSI values) of the samples extruded at 140℃ were comparable to those of extruded at 160℃. Although color values indicated that lightness (*L*) and yellowness (*b*) values of the extrudates did not change significantly at the barrel temperatures studied, extrudates were darker at the higher barrel temperature (160℃). BD values for extrudates ranged from 0.12 to 0.18 g/cm^3 at 140℃ and from 0.10 to 0.12 g/cm^3 at 160℃ (Table 1). Lower BD values of the samples produced at higher barrel temperature suggested that lighter extrudates were obtained at 160℃. This reverse relationship between temperature and BD is similar to the results previously reported by Taronto *et al.,* (1975)

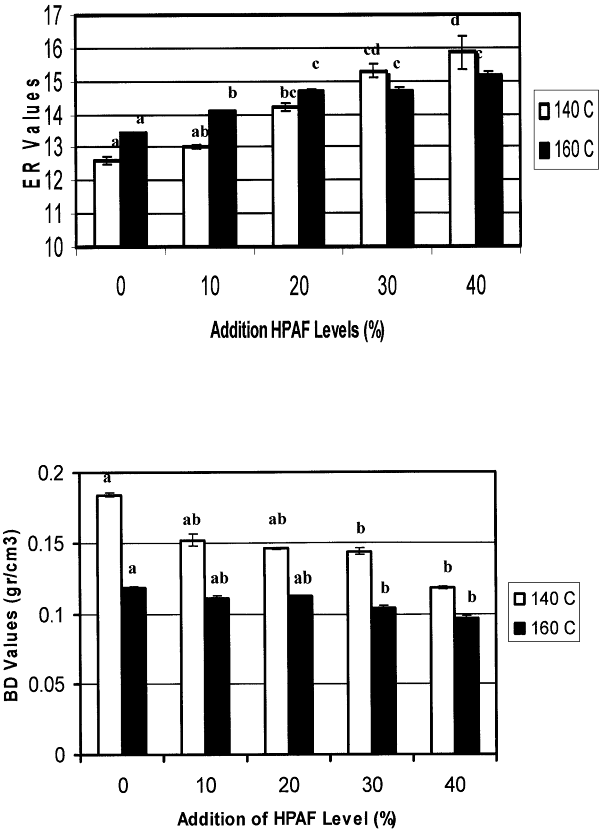

Fig. 1. Effects of high protease activity flour addition on bulk density and expansion ratio. The bars marked with the same letter are not statistically different ($p > 0.05$).

on cottonseed meal, Cumming *et al.,* (1972) on soybean meal, Lawton *et al.,* (1985) on wheat gluten and Bhattacharya and Hanna (1987) on corn starch.

Conclusion

Addition of HPAF into wheat flour at levels of up to 40% yielded more expanded products with lower bulk density. It has been proposed that expansion properties are mainly dependent on viscous and elastic properties of melted starch. The major influence of extrusion is to disassemble proteins and then rearrange them into a fibrous matrix with an oriented structure of characteristic texture (Anderson and Ng 2000, Fischer 2003). The unexpected positive effect of bug protease on quality parameters of extrudates can be attributed to depolimerization of gluten proteins by proteolytic activity (Sivri *et al.,* 1998, 1999). This depolimerization probably results in an increase in the initial uncooked viscosity, and promote reorganization of protein-starch complex. Therefore, it can be concluded that addition of HPAF positively affected BD and ER, which are important factors in product quality of extrudates at both process temperatures. As a result, HPAF, which is not suitable for bread making process due to high protease activity, could be successfully for use in extruded products. The findings of the study might be of some consequence for developing new ways to utilize low quality agricultural resources. This

Table 2. Mean values for physical properties of HPAF added to samples extruded at 140℃ and 160℃.

Physical Properties	Process Temperature	
	140 °C	160 °C
SME (J/g) *	708 ±87.0	587 ±50
BD (g/cm^3)*	0.15 ±0.0	0.11 ±0.0
WAI (g water/g dry sample)*	6.9 ±0.4	6.5 ±0.3
WSI (%)	24.3 ±1.7	24.7 ±2.8
ER	12.4 ±1.4	14.4 ±0.6
Lightness (L)	52.2 ±0.7	52.6 ±0.6
Redness (a)*	0.45 ±0.6	0.73 ±0.2
Yellowness (b)	5.0 ±0.4	5.5 ±0.8

* Statistically different ($p < 0.05$; Student's *t* test)
SME: Specific Mechanic Energy
BD: Bulk Density
WAI: Water Absorption Index
WSI: Water Solubility Index
ER: Expansion Ratio

is particularly important given that, at higher levels of damage (>10%), grain is usually rejected from milling grades of wheat and downgraded to feed grade (Karababa and Ozan 1998; Hariri *et al.* 2000).

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