Rheological and Quality Characteristics of Pasta Produced from Sunn Pest Damaged Wheat Flour and Ascorbic Acid

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ABSTRACT

Sunn pest, *Eurygaster integniceps,* is a major problem of wheat flours in Iran and adversely affects the characteristics of bakery products. This study was undertaken to improve the quality of pasta produced from different percentages of Sunn Pest Damaged Wheat Flour (SPDWF) using Ascorbic Acid (AsA). SPDWF was mixed with sound wheat flour at the levels of 3, 5, and 7%, and AsA at 200 and 300 ppm were added to 5 and 7% treatments. Doughs were evaluated in terms of rheological properties and the product was evaluated in terms of solid substances loss, baking number and sensory characteristics. Increasing the SPDWF decreased protein content, gluten index, and water absorption, while increasing AsA increased them significantly. Dough development and dough stability time were reduced by using highly infected treatments. AsA significantly improved 5% SPDWF and produced pasta similar to the 3% SPDF. Pasta made from higher damaged flour had no significant (P< 0.05) difference with the control in terms of taste, while it had lower values of acceptability, solid substance loss, and cooking number, and addition of AsA at the levels of 200 and 300 ppm cannot improved damaged flours.

INTODUCTION

Pasta is a staple food product that is produced mainly by mixing durum wheat semolina and water. It can be consumed after cooking as fresh pasta or can also be dried for future use. Common pasta produced with wheat has better quality parameters .Wheat flour, as the most important raw material required for production of pasta, contains unique gluten proteins. In pasta processing, gluten is mainly responsible for the formation of the structure. Gluten is considered to be the most significant factor related to pasta cooking quality. Gluten constitutes 80-85% of total wheat proteins and plays an important role in improving the appearance and structure of pasta. Gluten produces a continuous network and thus provides appropriate elasticity, plays important role in the formation of an appropriate structure and texture after cooking pasta, and is necessary for high quality pasta formulation (Don *et al*., 2003). Quality of pasta made from wheat flour is dependent on the quality and quantity of gluten. Gluten plays a key role and forms a three-dimensional structure and appropriate texture in dough, increases pasta strength and reduces stickiness and enameling during cooking pasta (Xu *et al*., 2007).

Pre-harvest damage to wheat caused by *Eurygaster spp.* occurs in many countries of the Middle East, Eastern Europe, and North

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Africa where it reduces wheat grain yield and baking quality. Insect infested grains contain a protease that breaks down the gluten structure of dough. Sunn pest's protease causes dough weakening by degrading polymeric glutenin, presumably through hydrolysis and possibly other mechanisms that affect the aggregation of gluten molecules. Despite the pest management, million tons of wheat is still harvested as bug-damaged every year as Sunn pest could not be eliminated. Compared to the sound kernels, the bug-damaged wheat kernel has no significant difference in physical characteristics, so, it could not be separated from the sound wheat kernels during cleaning of wheat prior to milling. Thus, it causes undesirable effect on the quality of the end product. Baking quality of the flour contaminated with bug-damaged kernel reduces due to bug originated proteolytic enzymes (Sivri *et al.*, 2004).

Bug attacked wheats have black spots due to the bug bite with a bright halo that can be associated with shrinkage of seeds. The pest saliva contains proteolytic enzyme that causes protein degradation, especially gluten, reduces elasticity of gluten and, therefore, makes it fluid. Dough from damaged wheat has low elasticity and weak cooking quality. Weak rheological properties and low consistency as well as reduced resistance of dough are caused by protease effect (Every *et al.*, 2005)

Ascorbic Acid (AsA) and its related compounds play an important role as improvers in bread production. AsA is included in the substance category which is deemed as non-hazardous and is normally present in the natural food composition. The advantages of the ascorbic acid use are: resistance to over boiling for pasta of a weak texture flour, lower loss of solid substances and decreased pasta agglomeration degree. AsA strengthens the structure of dough through oxidation of SH groups into S-S bridges. Their effect is more pronounced on the extensogram and alveogram through increasing dough resistance and decreasing extensibility. Addition of ascorbic acid and its related compounds, such as DeHydro-L-AsA (DHA) and 2,3-DiKeto-L-Gulonic acid (DKG), affect the rheological properties of flour-water dough during mixing, especially hardness. Addition of AsA increased the hardness of samples. (Olanca *et al.*, 2009).

Kostyukovsky *et al.* (2004) showed, presence of more than 5% Sunn pest flour produced doughs with low consistency, which have little resistance against mixing, difficult to transport, inappropriate texture, unusual shape, and low sensory properties. Del Nobil *et al.* (2005) investigated the effect of flour protein on cooking quality of spaghetti. The results showed a significant reduction in pasta adhesion by increasing protein, on the other hand, a descending trend was followed in cooking loss of samples and also pasta water absorption was increased by increasing protein. Ozderen *et al.* (2007) investigated bug damage on semolina properties and pasta quality characteristics. Results showed that by increasing the damaged wheat, dough strength was reduced, pasta was prone to breaking, and sensory properties showed a significant reduction. The pest protease collapse wheat gluten affecting the accumulation of gluten molecules (gluten molecules' aggregation inhibits).

Coultate (2009) stated that the use of improvers such as potassium bromate and ascorbic acid which cause oxidation of thiols groups to disulfide bonds is an appropriate solution to improve the properties of products made of infected wheat flour. Askari (1998) compared the effect of AsA and gluten on Sunn pest damaged flour. It was concluded that improvement effect of AsA on infected wheat was more than gluten.

This work was focused on the effect of different amount of SPDF and AsA on rheological properties of dough and quality characteristics of pasta to determine an acceptable ratio of SPDF and AsA in making pasta. The purpose of this study was

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to gain flour with features close to the control flour (normal sound flour with no pest damage).

MATERIALS AND METHODS

Sample Preparation

To prepare infected wheat flour, in the first step, 100% Sunn pest damaged wheat flour was prepared from wheat dockage screening. Then, infected wheat was isolated and milled by hammer mill. The infected flour was added to the main flour at the levels of 3, 5, and 7%. In each treatment, 200 and 300 ppm AsA (Merk) was added (Table 1). Flour, water and ascorbic acid were mixed until the appropriate dough was produced.

Pasta Preparation

To prepare dough, a portion of wheat flour was mixed with water. Control pasta was prepared with only *Triticum durum flour* (100 g). Details of the pasta formulation are provided in Table 1. Flour was mixed in Hobart mixer (model N-50, Ontario, Canada) using low speed of 0.4 g with optimal 30-40 mL of water 100 g^{-1} of flour and mixed for 7-10 minutes. Mixed samples were extruded using La Moniferrino (Model Dolly, Asti, Italy) pasta extruder. The samples were dried at 70°C for 3 hours in Sakar Drier (Shirsat Electronics, Mumbai) and packed in polypropylene covers for

Table 1. Treatments' profile.

Symbol	Treatment
A_0	100 % Semolina
A_1	97 % Semolina % + 3% SPDWF
A_2	95 % Semolina % + 5% SPDWF
A_3	93 % Semolina % + 7% SPDWF
A_4	A_2 + 200 ppm AsA
A_5	A_2 + 300 ppm AsA
A_6	A_3 + 200 ppm AsA
A_7	A_3 + 300 ppm AsA

further use.

Flour Chemical Analysis

Moisture, ash, protein, and wet gluten were measured according to AACC (2000) 44-1502 , 08-21-01, 38-10-01 and 38-10-01, respectively. Gluten index was evaluated by AACC 38-20-01.

Dough Rheological Tests

Water absorption, dough development time, and dough stability time were measured with mixograph according to ICC No. 173 (ICC, 2010). A sample of 35 grams of flour on a 14% moisture basis was weighed and placed in a mixograph bowl. Water was added to the flour from a burette and the bowl was inserted into the mixograph. The flour and water were mixed together to form a dough. As the dough was mixed, the mixograph recorded a curve on graph paper. The mixograph determines dough and gluten properties of a flour by measuring the resistance of a dough against the mixing action of pins. The amount of water added (absorption) affects the position of the curve on the graph paper. Less water increases dough consistency and moves the curve upward

Pasta Quality Tests

Glaze and cooking number were measured using AACC Method 66-50. Ten g of spaghetti were cooked in 300 mL of boiling distilled water. The cooking water was collected in an aluminum vessel, placed in an air oven at 105°C and evaporated until a constant weight was reached. The residue was weighed and reported as a percentage of the starting material. These analyses were made in triplicate. Sensory analysis was determined by standard five-point hedonic according to AACC 7409.

Statistical Analyses

All data were analyzed using the SPSS 18.0 software. Comparisons amongst means of samples were carried by ANOVA (Analysis of Variance) using the Duncan's multiple range test. Significant differences amongst mean values were considered at P< 0.05.

RESULTS AND DISCUSSION

Flour Tests Results

Mean comparison of samples (Table 2) revealed no significant correlation between moisture and ash, because all treatments were selected from the same type of wheat, with the same conditions of tempering and milling. Aalami *et al.* (2005) as well as Sung *et al.* (2003) confirmed this.

Control flour had the highest protein content and the least protein was observed in A_3 (7% SPDWF), A_6 (7% SPDWF+200 ppm AsA) and A_7 (7% SPDWF+300 ppm AsA).The lower values of protein obtained in treatments with higher amounts of SPDWF was due to the bug saliva protease that can hydrolyze the wheat proteins, especially gluten. As can be seen, adding AsA improved the gluten network. Oxidizing agents such as AsA, primarily

affect sulfur-containing amino acids, ultimately helping to form disulfide bridges between the gluten molecules. The addition of these agents to flour will create a stronger dough (Ozderen, 2007; Petrova, 2007). Wet gluten in the control treatment showed significant difference with other treatments (P< 0.05). Treatments A4 and A_5 had no significant difference with A_1, and A_6 and A_7 showed no significant difference with A_2. The highest wet gluten was related to the control dough and the lowest was seen in A_3. According to Figure 5, A_1, A_2, and A_3 had very low protein content and gluten index. The lowest gluten index was seen in A_3. Also, addition of AsA was significantly effective on A_2 (treatments with 5% SPDWF).

The addition of AsA improved protein network, therefore, treatments A_4, A_5, respectively, can show similar behavior to A1 (3% SPDWF) flour. The results are consistent with research of Ozderen (2007) and Coultat (2009) which investigate the Sunn pest damage on semolina properties and spaghetti quality characteristics of durum wheats. Proper pasta texture depends on the quantity and quality of gluten (Rao *et al.*, 2010). According to Table 1, in treatments A_1, A_2, and A_3, with 3, 5, and 7% SPDWF, the wet gluten was reduced by increasing SPDWF. Insect infested grains contain a protease that breaks down the gluten structure of dough. Sunn pest's protease causes dough weakening by

Table 2. Results of chemical analysis of flours.[a]

Test treatment	Moisture (%)	Protein (%)	Ash (%)	Protein (%)	Wet gluten (%)
Control	10.58 [a]	12.4 [a]	0.882 [a]	12.4 [a]	29.0 [a]
A_1	10.56 [a]	12.1 [b]	0.878 [a]	12.1 [b]	27.5 [b]
A_2	10.55 [a]	11.8 [c]	0.873 [a]	11.8 [c]	25.0 [c]
A_3	10.55 [a]	11.5 [d]	0.875 [a]	11.5 [d]	24.0 [d]
A_4	10.52 [a]	11.7 [c]	0.866 [a]	11.7 [c]	26.0 [b]
A_5	10.57 [a]	11.5 [c]	0.870 [a]	11.5 [c]	26.5 [bc]
A_6	10.56 [a]	11.5 [d]	0.877 [a]	11.5 [d]	25.0 [c]
A_7	10.54 [a]	11.5 [d]	0.883 [a]	11.5 [d]	24.5 [c]

[a] Mean in a column with similar superscript are not significantly different at $\alpha= 0.05$. Values are the means$\pm SD$ and $n= 3$ for each group.

degrading polymeric glutenin, presumably through hydrolysis and possibly other mechanisms that affect the aggregation of gluten molecules. AsA addition (at both levels of 200 and 300 ppm) significantly increased the wet gluten helping to form disulfide bridges between the gluten molecule (Figure 4) (Al-Mahasneh and Rababah, 2007).

Study showed a significant reduction of wet gluten content in treatments with high level of damaged grains. Gluten in wheat indicates dough consistency and elasticity; therefore, the lower the amount of protein, the lower will be the gluten content.

Wet gluten content depended on the variety and was in accordance with the protein content. Torbica *et al.* (2007) also indicated that by increasing the infected flour, gluten index was reduced. Dry gluten, wet gluten, and gluten index reflect the good quality of dough. Gluten index indicates dough consistency, the higher the amount of protein, the higher will be the gluten index. As can be seen in Table 1, by increasing SPDWF ratio, gluten index decreased significantly in A_1 to A_3 (with 3, 5, and 7 % SPDWF, respectively). Adding AsA to 3 and 5% of infected flours, caused significant difference in gluten index. The result indicated that the amount of wet gluten and gluten index showed a steady decrease with increasing insect attack (Sission, 2008). Addition of AsA to infected flour

significantly increases the water absorption due to improved gluten network and trapped water in the network (Every *et al.*, 2008)

Dough Rheological Tests

Water Absorption: Significant reduction (P< 0.05) in water absorption by increasing the SPDWF (Figure 1) was observed and, also, by increasing the ascorbic acid content, water absorption increased**.** The water absorption is the amount of water required to develop dough to the point of greatest torque when, for wheat flour, the gluten would have been fully developed.. Water absorption depends on many factors including the size of the flour particles, protein and starch, flour extraction rate, extent of infected flour, bran and Pentosanes. Regarding lower protein, in an infected wheat flour, water absorption is lower (Werteker, 2008). As can be seen in Figure 1, treatment A_3 (i.e. 7% SPDWF), had the least water absorption, while the control had the highest.

Dough Development Time: The least development time was related to A_3 (7% SPDWF). AsA increased dough development time significantly (Figure 2). Dough development time of A_4 and A_5 was close to A_1 and A_2. Development of dough occurs as a result of interactions among flour constituents during mixing operation. In treatments with 5% SPDWF (A_4, and A_5),
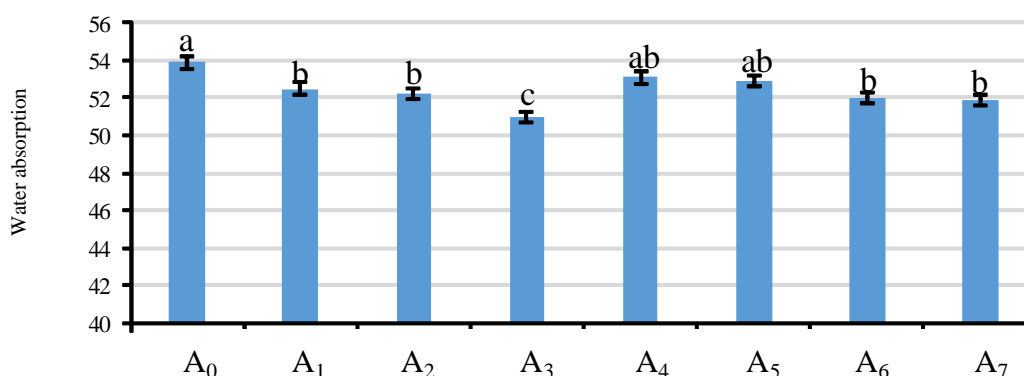

Figure 1. Water absorption of treatments with different levels of SPDWD and AsA. A_0 to A_7 are defined in Table 1.Similar superscripts are not significantly different at $\alpha= 0.05$
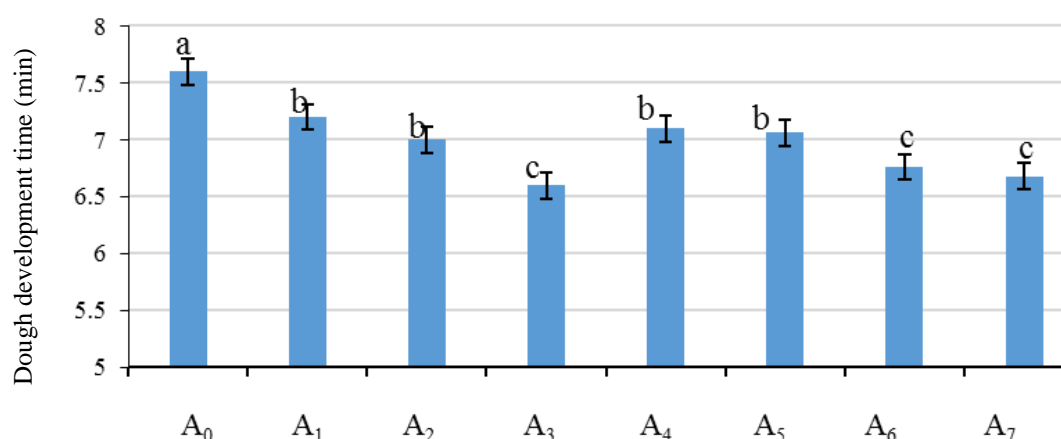
Figure 2. Dough development time of treatments with different levels of SPDWD and AsA. A_0 to A_7 are defined in Table 1. Similar superscripts are not significantly different at $\alpha= 0.05$
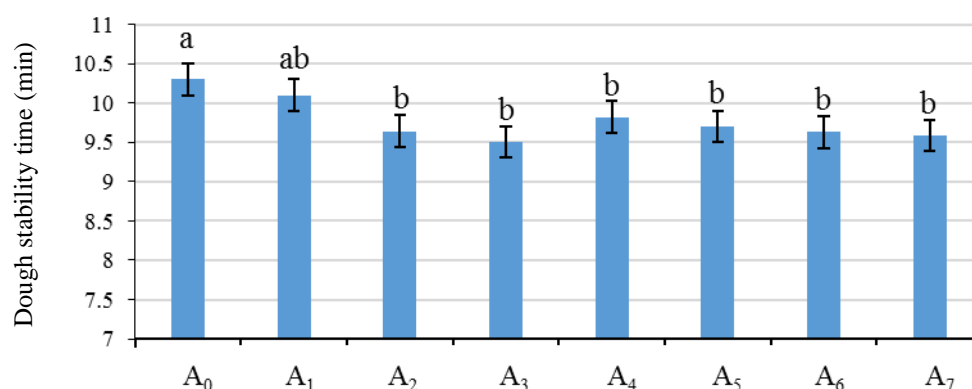

Figure 3. Dough stability time of treatments with different levels of SPDWD and AsA.

and 7% SPDWF (A_6, and A_7), AsA (both 200 and 300 ppm) caused no significant difference in dough development time.

Gluten development was mainly brought about by the interactions of glutenin proteins with each other in the loop by disulfide bonds. On further mixing, more protein becomes hydrated and the glutenins tend to align because of the imposed shear and stretching. The sticky characteristics of dough disappeared, viscosity increased and a non-sticky mass was developed at peak consistency of dough typified. The interactions between the polymers cross-links were stronger and led to an increase in dough strength. When the dough was mixed beyond its peak development, the cross-links began to break due to the breaking of

disulfide bonds. The glutenins become depolymerized and the dough is over-mixed. The monomeric proteins, gliadins form a matrix within the long polymer networks and contribute to resistance to extension by forming viscous dough with reduced elasticity. The presence of smaller chains, due to bug damage in flours, makes it stickier, decreased dough stability and dough development time (Blandino *et al.*, 2015).

Gabrilla *et al.* (2008) stated that different development time is related to gluten index. So, the reason for higher development time in the control flour can be attributed to the strength of gluten as well as gluten index. Dough development time index indicates relative strength of the control gluten and

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wheat not been damaged, which means that short development time shows poor gluten. Rao *et al*. (2010) concluded that strong wheat with a higher gluten index had higher dough development time.

Dough Stability Time: According to Figure 3, there is a significant difference between dough stability time of all treatments and the control (P< 0.05). The highest stability time was related to the control and the least was related to A_3. The stability time of A_4 and A_5 was close to A_1:. Stability time indicated the dough tolerance during mixing. AsA, due to oxidation of thiol bonds, resulted in a stronger flour and more viscose dough. In the presence of oxygen, AsA becomes an oxidizing agent and the 'improvements' to which it contributes include strengthened gluten. Dough stability is largely influenced by gluten quality indicating dough resistance to mixing force. If the stability time is more, the dough will be stronger. In the present study, AsA at the levels of 200 and 300 ppm did not increase the stability time of dough significantly. According to research of Gabrilla (2008), stability time depends on gluten. Dough prepared with flour from bug-damaged grains has an abnormal consistency due to its soft sticky gluten content, and kneading is very difficult. Baking is unsatisfactory and the resulting product has poor quality because of its crumbly texture (Aja, 2004; Al-Mahasneh and Rababah, 2007).

Results of Analysis of Product

Solid Substance Loss: As shown in Figure 4, the control treatment showed significant difference with the other treatments. By increasing the amount of Sunn pest flour, increasing in solid substance loss was observed. Addition of ascorbic acid caused significant decrease in solid substance loss. In general, the amount of solids in cooking water is called glaze .By increasing SPDWF, the solid substance loss was increased

(Figure 4). If gluten network is stronger as well as starch granules', solid substances loss is less. Dexter (2004) showed that protein is responsible for the maintenance of starch granules during cooking and prevents surface adhesion. The higher the protein quality and quantity, the less will be the solid substance loss. As can be seen in Figure 3, by increasing the SPDWF, the solid substance loss increased significantly. AsA addition decreased the solid loss due to strengthening the gluten network which is responsible for starch maintenance. As a result, in products with higher protein content, such as pasta produced from semolina without damage, it acts as an obstacle, prevents the removal of starch granules, and the solid loss decreases. Also, in higher damaged flour, because of easy removal of amylose into the cooking water, solid substance loss is higher (Dexter, 2004; Sission, 2008).

Cooking Number: Cooking number in the control treatment showed significant difference (P< 0.05) with all treatments. By increasing the Sunn pest flour, cooking number decreased. Ascorbic acid addition, increased the cooking number significantly (Figure 5). The highest cooking number was recorded in the control treatment which contained higher protein content and strong gluten network, and by increasing the SPDWF, cooking number was reduced, so that A_3 (with 7% SPDWF) had the lowest cooking number (Figure 5). Rao *et al.* (2010) found a significant relation between the quality of flour protein and pasta cooking number. In the control flour, due to higher protein content, a compact protein structure leads to the formation of a stable protein network, so that pasta texture is improved. The ability of the control sample, with no SPDWF to form an insoluble network during cooking, was higher than other samples and resulted in better pasta quality. In such products, proteins can withstand the physical stresses of cooking and impart firmness to the cooked product.
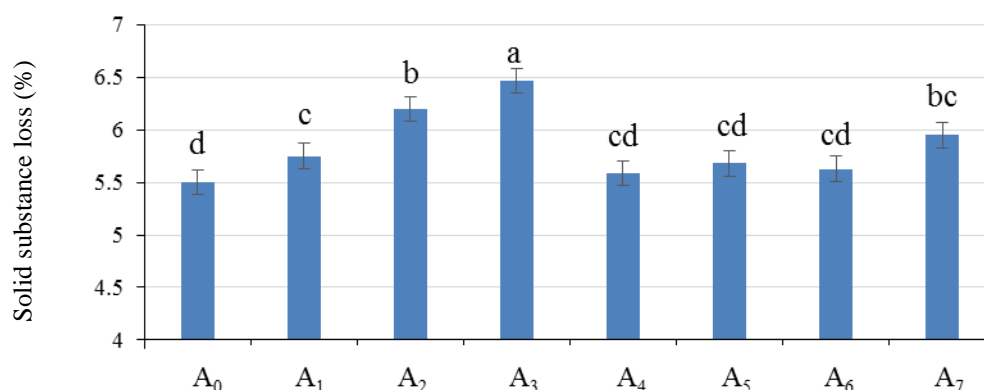
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Figure 4. Solid substance loss in pasta with different levels of SPDWD and AsA.
A_0 to A_7 are defined in Table 1. Similar superscripts are not significantly different
at $\alpha= 0.05$

Figure 5. Cooking number in pasta with different levels of SPDWD and AsA A_0 to A_7 are defined in Table
1. Similar superscripts are not significantly different at $\alpha= 0.05$
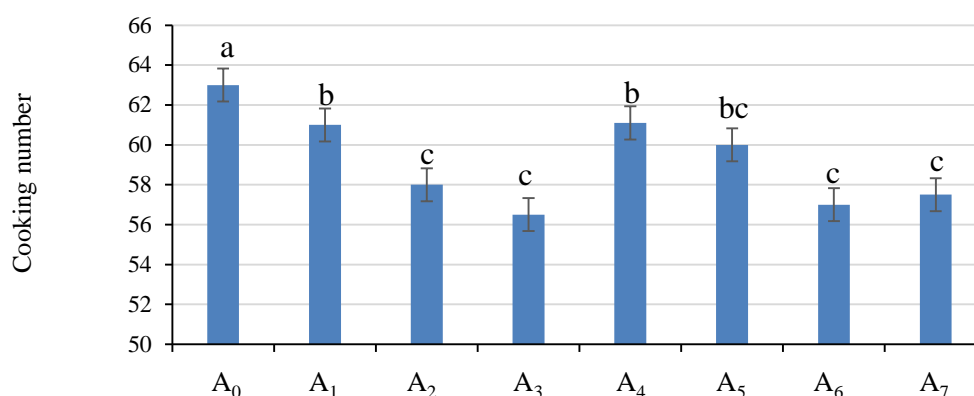
A_0 to A_7 are defined in Table 1. Similar
superscripts are not significantly different
at $\alpha= 0.05$

Sensory Evaluation: Sensory evaluation
results are shown in Table 3. As seen, the
highest acceptance is related to the control
dough and the least is related to A_3 (with 7%
Sunn pest flour).

The highest scores for texture related to
the control and the least related to A_3 (7%
SPDWF). AsA increased the scores of the
texture. If the pest level is reduced in
samples, firmness is increased due to better
gluten quality (Rao *et al*., 2010). A_3 had the
maximum softness and adhesion due to
lower level of gluten. Treatments with
higher levels of SPDWF, due to lower
protein quality, had more adhesion and
weaker texture; this led to greater
acceptance of the control sample from raters'
point of view

This result could be due to the fact that the
increase in SPDWF caused consequent
decrease in dough acceptability. This result
is correlated to that obtained for the
rheological properties. In fact, pasta with 7%
SPDWF showed lower value of
acceptability, adhesion, and texture
compared to the others. A_1 (with 3%
SPDWF) showed similar behavior to A_6 (3%
SPDWF+200 ppm AsA) and A_7 (3%
SPDWF+300 ppm AsA).

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Table 3. The results of sensory evaluation.

Hardness	Taste	General acceptance	Adhesion	General acceptance
4.6 [a]	3.4 [a]	4.1 [a]	4.2 [a]	4.1 [a]
4.3 [b]	3.4 [a]	3.8 [ab]	3.75 [b]	3.8 [ab]
3 [c]	3.4 [a]	2.75 [c]	2.9 [c]	2.75 [c]
2.3 [d]	3.3 [a]	2 [d]	2.1 [d]	2 [d]
3.2 [c]	3.3 [a]	3.7 [b]	3.1 [c]	3.7 [b]
3.2 [c]	3.2 [a]	2.95 [c]	3.1 [c]	2.95 [c]
2.7 [cd]	3.4 [a]	2.8 [c]	2.8 [c]	2.8 [c]
2.9 [cd]	3.3 [a]	2.7 [c]	2.9 [c]	2.7 [c]

Also, pasta made with SPDWF in terms of sensory characteristics such as odor and taste had no significant difference with the control (Rao *et al.,* 2010; Dexter, 2004).

CONCLUSIONS

Flour chemical tests results showed that there was no significant difference in moisture and ash among treatments. But, the highest level of protein, wet gluten, and gluten index related to the control treatment. Results also indicated that pasta made by SPDWF in terms of sensory characteristics such as taste and color had no significant difference with the control, while texture and adhesion obtained the lowest scores. Values showed that pasta made by less infected treatments with addition of 200 and 300 ppm AsA had better cooking quality. Pasta made with SPDWF and addition of 200 and 300 ppm AsA had no significant difference in dough stability and development time, but showed more water absorption. The present study showed that 5% SPDWF and addition of 200 and 300 ppm AsA can result in a pasta close to the 3% SPDWF. Significant difference was not found between 200 and 300 ppm of AsA.

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بررسی خواص رئولوژیکی و کیفی پاستای تهیه شده از آرد گندم سن زده و اسید اسکوربیک

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چکیده

حشره سن یکی از مشکلات اساسی آردهای گندم ایران بوده و به طور قابل ملاحظه ای سبب کاهش کیفیت محصولات پخت می گردد. در این تحقیق هدف بررسی اصلاح آرد گندم با مقادیر مختلف سن زدگی با استفاده از بهبود دهنده اسید اسکوربیک در تولید پاستا می باشد. بدین منظور ابتدا آرد گندم کاملا سن زده از دانه های سن زده گندم تهیه گردید و سپس از این آرد مقادیر۳, ۵, ۷ درصد به آرد سالم اصلی اضافه شد. به هر یک از تیمارها اسیداسکوربیک به عنوان بهبود دهنده به میزان ۲۰۰ و ۳۰۰ ppm استفاده گردید .خواص رئولوژیکی خمیر (جذب آب، پایداری خمیر و زمان گسترش خمیر) و همچنین خواص کیفی محصول از قبیل عدد لعاب و عدد پخت و ویژگیهای حسی مورد ارزیابی قرار گرفتند.نتایج نشان داد با افزایش نسبت سن زدگی خاکستر و رطوبت بدون تغییر بوده در حالی که مقدار پروتئین و کیفیت گلوتن ، جذب آب، زمان گسترش خمیر و پایداری خمیر کاهش معنی دار نشان داد. افزودن اسکوربیک اسید توانست در مقادیر فوق سبب بهبود خواص کیفی آزد گندم با 3% سن زدگی شده و محصولی مشابه با آرد گندم سالم تولید نماید. در پاستای تهیه شده از آرد گندم با درصد های بالاتر سن زدگی از نظر بو و طعم تفاوت معنی داری مشاهده نگردید اما از نظر خواص رئولوژیکی ، و کیفی از جمله اندیس لعاب و پخت کیفیت پایین داشته و با مقادیر ۲۰۰ و ۳۰۰ پی پی ام اسید اسکوربیک قابل اصلاح نبود.