Bread Quality Characteristics as Influenced by the Addition of Tomato Seed Flour

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Abstract
The aim of this investigation was to incorporate tomato seed into bread in order to improve its quality. For this purpose, wheat flour 650 type of a very good quality for bread making was replaced with tomato seed flour at the level of 5, 10, 15 and 20%. Bread quality through physical, colour, crumb cell, textural and sensory characteristics were analyzed and compared with those of bread without tomato seed. The substitution of wheat flour with 10% tomato seed has the effect of highest values for loaf volume, porosity and elasticity. Color intensity, expressed as the $L^*$, $a^*$, $b^*$ values of breads with tomato seed were lower than those of control bread. The hardness of bread samples increased with the increase level of tomato seed addition. Also, the addition of increasing amounts of tomato seed highlighted large cells in crumb structure of bread. Sensory characteristics showed that the addition of 5 or 10% tomato seed flour similar results from the point of view of overall acceptability, but 20% addition resulted in slightly acceptable samples. Principal Component Analysis revealed significant correlations ($p < 0.05$) between bread physical characteristics, loaf volume, porosity, elasticity and bread overall acceptability at different tomato seed flour addition levels in wheat flour. Overall, tomato seed flour could be incorporated up to a levels of 10% into bread in order to provide it beneficial health effects, without changing significantly bread quality.

Keywords: bread quality, principal component analysis, texture, tomato seed flour, wheat flour

INTRODUCTION
Tomato (Lycopersicon esculentum) is one of the most consumed vegetables, as raw (fresh), cooked, in food preparations, and as processed products such as tomato juice, puree, paste, ketchup, sauce and canned tomato (Kaur et al., 2006; Pinela et al., 2012). Processing of tomatoes led to a high amount of by-products consists mainly of skin and seeds (Del Valle et al., 2006) are promising sources of valuable compounds which may be used because their nutritional and medicinal properties. Tomato seeds account approximately 60% of the total by-product and contained appreciable amounts of protein (22.27-33.9%), fat (20.57-29.6%) (Sogi et al., 1998), fiber (35.1%), mineral elements such as potassium, calcium, iron, manganese, zinc and copper (Persia et al., 2003) and significant proportion of the antioxidants in the form of carotens and phenolic compounds (Knoblich et al., 2005). Shao (2013) reported that the tomato seed oil had total unsaturated fatty acid content up to 80.10% from which the major fatty acid beeing linoleic (53.70%), followed by oleic (23.80%) and linolenic acids (2.1%). Also, the defatted tomato seed contained six kinds of essential amino acids, with histidine, an essential amino acid for infants, as the most dominant (23.34%). Quality evaluation of tomato seed protein revealed that the nutritive value of tomato seed protein was less than that of casein but equivalent to other plant proteins (Kramer and Kwee, 1977). Substantial amounts of digestible amino acids, especially lysine (Brodowski and Geisman, 1980; Cantarelli et al., 1989; Persia et al., 2003) were found, suggesting that tomato seed can be used in fortifying various low-lysine products that are deficient in this
amino acid like wheat flour (Yaseen et al., 1991). No anti-nutritional factor or harmful constituent have been reported in tomato seeds (Rahma et al., 1986).

The use of tomato seeds separated from tomato pomace have been the subject of significant research during the last years aiming especially to improved nutritional quality of some foods (Carlson et al., 1981; Sogi et al., 2002). In bread making product different research has been made regarding the effect of tomato seed flour incorporation in wheat flour on final product quality (Carlson et al., 1981; Sogi et al., 2002; Yaseen et al., 1991). Sogi et al. (2002) reported that good sensory characteristics and improved protein quality can be obtained in bread supplemented with 10% defatted seed flour. On bread quality characteristics Morrison (1976) found that tomato seed flour addition improved loaf volume, texture and crumb quality, due to anti-staling properties, for all sample compared to the control one, and Yaseen et al. (1991) found that the bread with the addition of 1 or 2% tomato seed flour to the wheat flour were similar in quality to the control wheat bread, but higher additions resulted in crumb darkening. Zagibalov et al. (1985) found that the taste score decreased as the level of tomato seed flour increased, and a slightly bitter taste at a 10% or higher replacement level may be due to a steroid compound found in crushed tomato seed.

MATERIALS AND METHODS

The research has been carried out on a commercial wheat flour (harvest 2015) 650 type perched from Mopan S.A. (Suceava, Romania). Tomato seeds were manually separated from the pomace collected from a tomato juice-manufacturing, dried at 40°C in an oven for 24 h to a moisture content of 5.0% ± 0.2%. Dried tomato seeds were ground (electrical grinder, Heinner, Navy 150, China) to get whole flour. Dried tomato seeds were ground to get whole flour. Wheat flour (WF) and tomato seed flour (TSF) were analyzed for its chemical characteristics (moisture, protein, fat, and ash) according to ICC methods. The WF was also analyzed for wet gluten (ICC 106/1), gluten deformation index (SR 90:2007) and falling number (ICC 107/1).

WF and TSF in different doses (0% - control sample, 5%, 10%, 15%, 20%) for prepared bread samples was used. Compressed yeast and salt were added in doses of 3% respectively 1.5% reported to the mass of the wheat-tomato seed flour and water up to 56.3% wheat flour hydration capacity. After all the ingredients were added, the dough was kneading in a laboratory mixer for 15 min and then modeled and placed to the fermentation at 30°C and 85% relative humidity for 60 min. The fermented dough’s were baked in an oven (Caboto PF8004D, Italy) for 30 min at 180 ± 5°C and then, the bread samples were removed from the pans and cooled at room temperature.

The bread physical properties, loaf volume - determined by the rapeseed displacement method, porosity, elasticity were measured according to SR 91:2007.

Crumb colour was determined using a Konica Minolta CR-700 colorimeter. The colorimeter was calibrated using a standard white plate. The colour parameters expressed in terms of L* (lightness and darkness), a* (redness and greenness) and b* (yellowness and blueness), its deviations, ∆L*, ∆a* and ∆b*, and total colour difference ∆E*, were recorded.

Textural parameters of bread, primary parameters hardness, cohesiveness and elasticity, and secondary texture parameters, gumminess and chewiness, can be obtained from a texture profile analysis (TPA) test using a Mark-10-ESM301 texture analyzer. The data interpretation was made by using a Mesur Gauge software of Mark 10 texturometer.

The MoticSMZ–140 stereo microscope with the 20x objective to a resolution of 2048 x 1536 pixels was used to analyze the crumb cells.

The bread sensory characteristics including appearance, colour, flavour, taste, smell, texture and overall acceptability were evaluated on a 1 - 9 hedonic scale (1 - dislike extremely, 2 - dislike very much, 3 - dislike moderately, 4 - dislike slightly, 5 - neither like nor dislike, 6 - like slightly, 7 - like moderately, 8 - like very much, 9 - like extremely) by using a panel of thirtyeth semi-trained judges.

Microsoft Excel 2007 and the Statistical Package for Social Science, v16.0 was used for statistical analysis. Results were considered statistically significant at p < 0.05.

RESULTS AND DISCUSSION

As TSF and WF were the main ingredients used in bread formulation, the analytical characteristics were determined and the results are reported in
Table 1. It is remarkable that TSF contained much less moisture that the wheat flour (Tab. 1). The protein content of TSF was reasonably high when compared with WF. Because of this fact, tomato seeds are an important source of proteins than can be used for nutritional consideration to improve overall protein quality of bread, in agreement with the results obtained by Sogi et al. (2002). Comparatively with other studies (Carlson et al., 1981), the fat content in TSF was lower (19.5%). Tomato seed have been reported to contain relatively high levels of minerals (3.92) and so it was no surprise to find the ash content was sixfold that of wheat flour.

Regarding the quality parameters of WF, the results obtained suggested that the WF is of a very good quality from bread making, with a gluten deformation index of 8 mm. However it shows a high falling number value due to it low alpha-amylase activity (Codină et al., 2012).

The loaf volume, porosity and elasticity of breads made with some TSF are shown in Figure 1. Loaf volume is influenced by many factors such as WF compositions, additives and dough fermentation conditions (Rosell et al., 2001). The loaf volume of bread made by including up to 20% TSF did not show a significant difference (p > 0.05) when compared with the loaf made without TSF. The highest volumes obtained by breads supplemented with 10% TSF, followed by formulation with TSF at 5% TSF (Figure 1). The improving effect of TSF on volume of bread (Carlson et al., 1981) as well, as on wheat flour breads (Carlson et al., 1981; Sogi, 2002) has also been reported by various authors. A possible explanation to this result is probably due to slightly amylase activity of tomato seed flour that can improve dough development and gas retention (Rosell et al., 2001) and thus the volume of bread. However, samples with the addition of TSF over

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Tomato seed flour</th>
<th>Wheat flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>6.94 ± 0.05</td>
<td>14.50 ± 0.04</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>29.50 ± 0.27</td>
<td>12.60 ± 0.22</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>19.50 ± 0.06</td>
<td>1.50 ± 0.02</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>3.92 ± 0.06</td>
<td>0.65 ± 0.05</td>
</tr>
<tr>
<td>Gluten deformation (mm)</td>
<td>-</td>
<td>8.00 ± 0.6</td>
</tr>
<tr>
<td>Falling number (s)</td>
<td>-</td>
<td>380.00 ± 19</td>
</tr>
</tbody>
</table>

Fig. 1. Effects of substitution ratio on physical characteristics of tomato seed flour incorporated breads
15% have a smaller volume compared to the sample with 5 and 10% TSF addition. A decreasing in loaf volume can be attributed to the reduction in gluten content of composite flour as a result of TSF incorporation in WF, the dough couldn’t retaining so well the fermentation gases. These results are in accordance with those of Carlson et al. (1981) who reported a decrease in loaf volume of bread with the addition of 20% defatted TSF. A high concentration of crude fat present in the tomato seed appearing to be responsible for the increase in loaf volume (Carlson et al., 1981).

Other physical characteristics, as factors that decisively affect the bread quality, are the porosity and elasticity of the bread samples. Fig. 1 shows that an increase of the TSF in WF increase the loaf porosity and elasticity up to 10% and then decrease them at the level of 15% and 20% TSF addition, respectively. Compared to the control formulations, the porosity increased in the case of TSF addition at 5 and 10% level. The incorporation of TSF into wheat bread improved crumb grain by stabilizing air cells in the bread dough and preventing coalescence of the cells, according to the result obtained by Wang et al. (1998). The elasticity of bread made by adding up to 15% TSF did not show a significant difference when compared with the elasticity of the control. Higher concentrations of TSF resulted in a less elastic crumb. A less wheat gluten in the formulation samples may retain less fermentation gas, this may be the primarily reason for the decrease in elasticity of bread containing 20% TSF.

Table 2 shows the changes in the colour of bread crumb. The results indicate that addition of TSF in bread formulation reduces bread lightness. The brightness values $L^*$ decrease with increasing level of TSF added to bread due to the darker TSF colour compared to white WF. The redness of the bread increased with the increase of the TSF in the formulation. Determination of the $b^*$ value showed that by increasing the TSF level in the bread formulation, the crumb $b^*$ value increased, particularly when TSF level was at 5%. On the other hand, the yellowness of the bread samples increased as the result of addition of TSF. The significant enhancing of total colour difference $\Delta E^*$ values of breads with TSF addition in comparison to control breads, without TSF addition, were also observed.

The texture profile analysis revealed that TSF addition in different levels in WF has significant effects on the texture parameters of bread samples (Tab. 3). The hardness of the bread increases

<table>
<thead>
<tr>
<th>Tomato seed flour (%)</th>
<th>$L^*$</th>
<th>$a^*$</th>
<th>$b^*$</th>
<th>$\Delta L^*$</th>
<th>$\Delta a^*$</th>
<th>$\Delta b^*$</th>
<th>$\Delta E^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>74.46</td>
<td>-1.87</td>
<td>13.35</td>
<td>38.64</td>
<td>-15.22</td>
<td>-0.87</td>
<td>41.54</td>
</tr>
<tr>
<td>5</td>
<td>64.95</td>
<td>-1.68</td>
<td>15.77</td>
<td>-27.64</td>
<td>-2.62</td>
<td>11.56</td>
<td>30.07</td>
</tr>
<tr>
<td>10</td>
<td>61.80</td>
<td>-1.58</td>
<td>16.64</td>
<td>-30.79</td>
<td>-0.91</td>
<td>12.43</td>
<td>33.21</td>
</tr>
<tr>
<td>15</td>
<td>60.97</td>
<td>-1.27</td>
<td>16.30</td>
<td>-31.62</td>
<td>-0.60</td>
<td>12.09</td>
<td>33.86</td>
</tr>
<tr>
<td>20</td>
<td>58.19</td>
<td>-0.27</td>
<td>17.10</td>
<td>-34.40</td>
<td>0.40</td>
<td>12.89</td>
<td>36.74</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tomato seed flour (%)</th>
<th>Hardness (N)</th>
<th>Cohesiveness</th>
<th>Elasticity</th>
<th>Gumminess (N)</th>
<th>Chewiness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16.22</td>
<td>0.69</td>
<td>0.82</td>
<td>11.19</td>
<td>9.62</td>
</tr>
<tr>
<td>5</td>
<td>16.92</td>
<td>0.69</td>
<td>0.87</td>
<td>11.65</td>
<td>10.19</td>
</tr>
<tr>
<td>10</td>
<td>12.88</td>
<td>0.66</td>
<td>0.79</td>
<td>8.45</td>
<td>6.68</td>
</tr>
<tr>
<td>15</td>
<td>19.68</td>
<td>0.80</td>
<td>0.76</td>
<td>15.69</td>
<td>11.91</td>
</tr>
<tr>
<td>20</td>
<td>21.11</td>
<td>0.62</td>
<td>0.82</td>
<td>14.33</td>
<td>11.74</td>
</tr>
</tbody>
</table>
to a certain level of TSF added in WF. Maximum hardness was found for bread with 20% TSF addition probably due to the dilution of the gluten proteins. For the cohesiveness and elasticity, the higher values were recorded for the samples with 15% and 5% TSF addition, respectively. The higher gumminess and chewiness values were recorded for the sample with 15% TSF addition in WF.

The image analysis of the bread crumb structure is presented in Fig. 2.

As can see, the crumb appears more compact in wheat bread without TSF addition. This may be attributed to dough elasticity that allows cell expansion during fermentation which can retain well the gas formed. The addition of TSF at high levels had a great impact on the crumb structure; the crumb doesn't seem very compact and large cells can be noticed maybe due to the gas losses during baking, gas that can not be anymore very well retain by the tomato seed - wheat dough. The crumb of the breads with 5% TSF were golden, while at higher levels of addition they were darker (Yaseen et al., 1991). The same effects on the crumb colour was observed by the Mokhnacheva...

![Fig. 2. Crumb structure of bread samples](image-url)
et al. (1975) which reported that wheat breads baked with 1 or 2% TSF added to WF were equal in quality to control wheat bread, but greater additions resulted in crumb darkening.

The sensory evaluation results (Fig. 4) reveal significant differences between control sample and bread with tomato seed at different levels.

The increasing level of TSF had a positive effect on bread texture as higher scores were given to the samples containing up to 10% TSF. The addition of higher levels of TSF (15 and 20%) had a negative effect on texture, and also on smell and taste. Taste score decreased as the level of TSF increased. The results show that the sample containing 10% TSF or higher replacement level received lower scores compared with sample with 5% TSF. A slightly bitter taste at a higher addition level may be due to a steroid compound found in crushed tomato seed (Zagibalov et al., 1985). The overall acceptance of the samples was lower when levels of 15 and 20% TSF were added in WF. A similar result was found by Constandache (2005) which highlight that additions of TSF greater than 2% have a negative effect on bread quality. It seems that the overall acceptance was affected by the taste and smell of the bread rather than the texture, former parameters that were poor at level of 20% TSF added in WF bread.

The relationship between the bread flour characteristics at different TSF substitution levels (0, 5, 10, 15 and 20%) evaluated by principal component analysis (Fig. 4.) revealed that the first two principal components explain 83.75% of the total variance (PC1 = 50.43% and PC2 = 33.32%). The first principal component, PC1 is strongly correlated with colour parameter $L^*$ and sensory characteristics smell, flavour and taste. Therefore, high correlations were obtained between smell and flavour ($r = 0.984, p < 0.01$), between taste and smell ($r = 0.940, p < 0.05$), and between taste

![Fig. 3. Sensory characteristics of bread samples](image)

![Fig. 4. Principal component analysis for the bread characteristics](image)
and flavour (r = 0.899, p < 0.05). The PC1 axis distinguishes the $a^*$, $b^*$ colour parameters and the $L^*$ parameter, which are opposed. A negatively significant correlation was found between $L^*$ and $a^*$ ($r = -0.739$, $p < 0.05$) and, between $L^*$ and $b^*$ ($r = -0.990$, $p < 0.01$).

The second principal component, PC2 is strongly correlated to bread physical characteristics, loaf volume, porosity and elasticity, and sensory characteristics colour, appearance, texture and overall acceptability. Significant correlation ($p < 0.05$) have obtained between loaf volume and texture ($r = 0.87$), appearance ($r = 0.91$), and overall acceptability ($r = 0.86$). The PC2 axis underlines the opposition between sensory characteristics elasticity, porosity and textural parameters, hardness, gummyness and chewiness.

CONCLUSION

The tomato seed composition showed that these seeds are suitable for use in bread-making. It may be concluded that the addition of tomato seed flour to wheat flour bread increases nutritional value and it technological quality. The tomato seed flour addition influence bread physical, colour and it textural parameters. Addition of tomato seed flour in bread formulation caused a decrease in $L^*$ an $b^*$ values, while $a^*$ values increased in bread crumb color. This study showed that TSF can be used to replace WF in bread production up to a level of 10%, with moderate impact on bread sensory characteristics.

The principal component analysis of the data set indicated high correlations between bread physical characteristics and some of the sensorial characteristics of bread.

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