FULL LENGTH ARTICLE

Effect of toasting on physical, functional and antioxidant properties of flour from oat (Avena sativa L.) cultivars

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Abstract Oat cultivars were toasted and studied for their physical properties (1000 kernel weight, bulk density, and l/b ratio). Both the control and toasted samples were milled into flour and studied for their functional (water absorption capacity, WAC; oil absorption capacity, OAC), color (L*, a*, b* values), and antioxidant (total phenolic content, TPC; antioxidant activity, AOA; metal chelating activity, MCA; and total flavonoids content, TFC) properties. Toasting resulted in significant (p < 0.05) decrease in physical parameters, hunter L* value, and TFC. However, it resulted in increase in WAC, OAC, hunter a* and b* values, TPC, AOA and metal chelating values. Toasting increased TPC, AOA, and MCA by 11.5–27.1%, 29.1–53.6%, 33.9–74.4%, respectively and decreased TFC by 23–40.1%. Pearson correlation coefficients (r) were also calculated to study the relationships among various properties studied. AOA exhibited a positive correlation (r = 0.931, p < 0.05) with TPC which upon toasting showed a decrease (r = 0.851, p < 0.05). TPC, AOA, MCA, and TFC of control oat cultivars varied from 1744 to 2687 µg GAE/g, 11.9% to 15.3%, 28.4% to 46.2%, and 433 to 612 µg CE/g, respectively.

1. Introduction

Oat (Avena sativa L.) ranks sixth in world production and almost 96,08,318 hectares of land are under oat cultivation with total production of 21.06 Million tonnes (FAO, 2012). Carbohydrate, predominantly starch (/C24 60 g/100 g), and soluble fiber (β-glucan), which ranges from 1.8 to 7.5 g/100 g are the major components in oat groats (Bhatty, 1992). Oats being a good source of soluble dietary fiber β-glucan and unsaturated fatty acids, also contain bioactive phytochemicals such as vitamins, phenolic acids, and avenanthramides (Welch,
β-glucan is found effective in reducing serum cholesterol concentration and postprandial blood glucose level (Tiwari and Cummins, 2009) and has good water binding and emulsion stabilizing properties, thus it has been used in different food products to improve the textural and rheological properties (Lazaridou and Biliaderis, 2007).

Thermal processing is the most extensively used method applied to cereals for improving their texture, palatability and nutritive value by gelatinization of starch, denaturation of proteins, increased nutrient availability, inactivation of heat labile toxic compounds and other enzyme inhibitors (Bakr and Gowish, 1991). Toasting is a rapid processing method that uses dry heat for short periods of time. In India, toasted and roasted cereals are consumed in the form of “sattu” which is a good source of natural fiber and carbohydrate. The toasted grain exhibits improved texture, enhanced crispiness and volume due to puffing and improves the digestibility, color, flavor, shelf life and reduces the antinutrient factors of cereals. Ovando-Martinez et al. (2013) found that oat grains kilned at 88–115°C for 90–120 min gave more intense flavor to the oat product and denatures approximately 60–80% of lipase in the grain. As toasted grains have numerous health benefits and they improve product quality, the present investigation thus aimed to study the effect of toasting on functional, color, and antioxidant properties of flours from different oat cultivars grown in India.

2. Materials and methods

2.1. Procurement of oat samples

Five commonly grown hulled oat cultivars (cv.) namely OS-6, OS-7, OS-346, HF0-114 and Kent were collected from Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India. The grains from these cultivars were cleaned and stored in a refrigerator till further evaluation.

2.2. Reagents

Standard gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferrozine, Folin–Ciocalteu’s, ABTS and catechin were purchased from Sigma–Aldrich (Steinheim, Germany). All chemicals were of analytical grade.

2.3. Toasting, dehusking and milling of oats

Toasting of oat cultivars was done by following the method of Fares and Menga (2012). Oat cultivars (200 g each) were conditioned to moisture content of 10% to maintain uniformity during toasting process and then toasted at 115 ± 2°C for 3 h in an oven. Both the control and toasted grains were placed in the polishing chamber and the polisher was run till the husk was completely removed from the grain. Oat flour was prepared by grinding dehusked oat in a super mill and flour thus obtained was sieved through 250 mm sieve.

2.4. Physical properties of oat cultivars

Physical properties of oat cultivars were measured by following the method of Sandhu et al. (2007). Oat grains were randomly selected and 1000 kernels of grains were counted. The counted grains were then weighed and expressed in grams. All the measurements were triplicated. For measuring the bulk density, grains were gently filled in a 100 ml graduated cylinder, previously tared. The bottom of the cylinder was gently tapped on a laboratory bench, several times, until there was no further diminution of the sample level after filling to the 100 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/100 ml). All the measurements were triplicated. l/b ratio was calculated using vernier caliper. The puffing index was calculated by dividing the bulk density of control with bulk density of toasted samples.

2.5. Proximate analysis

Oat flour from different cultivars was tested for moisture, ash, fat, fiber and protein contents, by employing the standard methods of analysis (AOAC, 1990). The carbohydrate content was calculated by difference. All the results were recorded on a dry weight basis (dw).

2.6. Water and oil absorption capacity

Water absorption capacity of flours was measured by the centrifugation method described by Sosulski (1962). For determination of fat absorption capacity the method of Lin et al. (1974) was followed.

2.7. Foaming capacity and foaming stability

The foaming capacity and stability were determined by following the homogenization method described by Lin et al. (1974).

2.8. Emulsion activity and stability

Emulsifying properties were determined by following the homogenization method described by Naczk et al. (1985).

2.9. Color characteristics of oat flour

Color measurement of flour was carried out using a Hunter Colorimeter fitted with optical sensor (Hunter Associates Laboratory Inc. Restan VA., USA) on the basis of L*, a*, b* color system.

2.10. Total phenolic content (TPC)

The total phenolic content was determined by following the Folin–Ciocalteu spectrophotometric method described by Gao et al. (2002). Oat flour samples (200 mg) were extracted with 4 ml acidified methanol (HCl/methanol/water, 1:80:10, v/v/v) at room temperature (25°C) for 2 h using wrist action shaker (Narang Scientific, Delhi, India). The mixture was centrifuged at 3000 rpm for 10 min on a centrifuge. The supernatant was used for determination of total phenolic content. Aliquot of extract (200 µl) was added to 1.5 ml freshly diluted (20-fold) Folin–Ciocalteu reagent. The mixture was allowed to equilibrate for 5 min and then mixed with 1.5 ml of sodium carbonate solution (60 g/l). After incubation at room temperature (25°C) for 90 min, the absorbance of the mixture was...
read at 725 nm. Acidified methanol was used as a blank. The results were expressed as μg of gallic acid equivalents (GAE)/g of flour.

2.11. Total flavonoids content (TFC)

The total flavonoids content was determined as previously described by Jia et al. (1998). Oat extract (250 μl) was diluted with 1.25 ml distilled water. Sodium nitrite (75 μl of 5 ml/100 ml solution) was added and the mixture was allowed to stand for 6 min. Further, 150 μl of a 10 ml/100 ml aluminum chloride was added and the mixture was allowed to stand for another 5 min. After that, 0.5 ml of 1 mol/l sodium hydroxide was added and solution was mixed well. The absorbance was measured immediately at 510 nm using a spectrophotometer. Catechin was used as standard and the results were reported as μg of catechin equivalents (CE)/g of flour.

2.12. Antioxidant activity using DPPH

Antioxidant activity was measured using a modified version of the method explained by Brand-Williams et al. (1995). This involved the use of free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution in the methanol. Ground oat samples (100 mg) were extracted with 1 ml methanol for 2 h and centrifuged at 3000 rpm for 10 min. The supernatant (100 μl) was reacted with 3.9 ml of a 6 × 10⁻⁵ mol/l of DPPH solution. Absorbance (A) at 515 nm was read at 0 and 30 min using a methanol blank. Antioxidant activity was calculated as % discoloration.

\[
\% \text{ Antioxidant activity} = \left(1 - \frac{A}{C_0} \right) \times 100
\]

2.13. Metal chelating (Fe²⁺) activity

The metal chelating activity of oat extract was measured as reported by Dinis et al. (1994). The extract (0.5 ml) was mixed with 50 μl of ferrous chloride (2 mMol/l) and 1.6 ml of 80% methanol was added. After 5 min, the reaction was initiated by the addition of 5 mMol/l ferrozone (100 μl) and the mixture was shaken on vortex. The mixture was incubated at room temperature (25°C) for 10 min. Absorbance of solution was measured at 562 nm on a spectrophotometer. The chelating activity of the extract for Fe²⁺ was calculated as follows:

Iron (Fe²⁺) chelating activity(%) = \left(1 - \frac{\text{Absorbance of sample} - \text{Absorbance of control}}{\text{Absorbance of sample}}\right) \times 100

2.14. Statistical analysis

The data shown in all the tables are an average of triplicate observations and were subjected to one way analysis of variance (ANOVA) using Minitab statistical software version 14 (Minitab Inc, USA). The Pearson correlation coefficients (r) for relationships between various properties were also calculated.

3. Results and discussion

3.1. Physical parameters and proximate composition of oat cultivars

The physical parameters of oat cultivars are shown in Table 1. 1000 kernel weight was significantly (p < 0.05) different among cultivars and varied from 20.5 to 27.8 g, the highest and the lowest being observed for cv.HFO-114 and cv.OS-7, respectively. Toasting resulted in a decrease in 1000 kernel weight (7.7–20.6%) and the decrease was more pronounced for cv.Kent. The bulk density varied from 0.732 to 0.770 g/100 ml among cultivars; toasting decreased the bulk density which may be due to loss of integrity between starch–starch and starch–protein matrix and or due to formation of spaces in the starchy endosperm (Chandrasekhar and Chattopadhyay, 1990). Gujral et al. (2011) reported a decrease from 31% to 44% for bulk density after roasting of oats. Toasting also led to decrease in l/b ratio by 10.3% to 21.4%, which may be attributed to the expansion of grains along its breadth. l/b of control sample was highly positively correlated with bulk density (r = 0.986, p < 0.05) with roasted decreasing the correlation (r = 0.914, p < 0.05). Puffing index of toasted samples ranged between 1.14 and 1.22, with cv.OS-346 and cv.Kent, showing the highest index which showed their greater expansion in comparison with other toasted oats. Proximate composition of flours is shown in Table 2. The ash and fat content varied from 2.6 to 3.9 g/100 g and 4.2 to 5.3 g/100 g, respectively, the highest being observed for cv.OS-346. Cv.'s OS-6 and HFO-114 showed the lowest ash and fat contents, respectively. The protein content ranged between 12.9 and 14.4 g/100 g, with cv.'s OS-6, OS-346 and Kent showing the nonsignificant difference. A positive correlation exhibited between protein content and 1000 kernel weight (r = 0.892, p < 0.05) which upon roasting was decreased (r = 0.644, p < 0.05). Crude fiber content was observed to be lowest for cv.OS-7 (10.9 g/100 g) and the highest for cv.OS-346 (13.3 g/100 g). Carbohydrate content that was calculated by difference and the values ranged between 55.7 and 59.9 g/100 g. Usman et al. (2010) reported ash, fat, protein, fiber, and carbohydrate contents of 3.7, 4.5, 13.5, 12.4, and 60 g/100 g, respectively for oat grains.

3.2. Functional properties of flours

Water absorption capacity (WAC) varied significantly (p < 0.05) among different flours and ranged from 167 to 195 g/100 g, with cv.HFO-114 and cv.Kent showing the highest and the lowest values (Table 3). Toasting led to increase in WAC with cv.Kent showing the maximum increase (51.4%). The increase in WAC after toasting can be attributed to starch damaged due to gelatinization and formation of porous structure in the endosperm, which imbibes and holds water by capillary action (Mariotti et al., 2006a,b). Cv.HFO-114 showed the highest values for OAC for both control and toasted samples, with toasting increasing OAC by 5.6–15.9%. Foaming capacity (FC) and foam stability (FS) are used as indices of the whipping properties of protein isolates (Mwasaru et al., 1999). FC of flours from different cultivars differed significantly (p < 0.05) with values ranging between
Table 1  Physical parameters of control and toasted oat from different cultivars.

<table>
<thead>
<tr>
<th>Oat cultivars</th>
<th>1000 kernel weight (g)</th>
<th>Bulk density (g/ml)</th>
<th>l/b ratio</th>
<th>Puffing index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Control)</td>
<td>(Toasted)</td>
<td>(Control)</td>
<td>(Toasted)</td>
</tr>
<tr>
<td>OS-7</td>
<td>20.5**(a)</td>
<td>18.5**(b)</td>
<td>0.75**(a)</td>
<td>0.65**(b)</td>
</tr>
<tr>
<td>OS-6</td>
<td>24.6**(a)</td>
<td>22.6**(b)</td>
<td>0.74**(a)</td>
<td>0.62**(b)</td>
</tr>
<tr>
<td>OS-346</td>
<td>26.7**(a)</td>
<td>23.7**(b)</td>
<td>0.75**(a)</td>
<td>0.61**(b)</td>
</tr>
<tr>
<td>HFO-114</td>
<td>27.6**(a)</td>
<td>23.7**(b)</td>
<td>0.72**(a)</td>
<td>0.64**(b)</td>
</tr>
<tr>
<td>Kent</td>
<td>25.7**(a)</td>
<td>20.4**(b)</td>
<td>0.77**(a)</td>
<td>0.66**(b)</td>
</tr>
</tbody>
</table>

a, b, c, d, and e superscript are significantly \((p < 0.05)\) different column wise within different cultivars and \(p\) and \(q\) superscript are significantly \((p < 0.05)\) different row wise within a cultivar. Subscripts denote the percentage decrease \((\%\) from control samples for corresponding properties.

Table 2  Proximate composition of flour from different oat cultivars.

<table>
<thead>
<tr>
<th>Oat cultivars</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Crude fiber (%)</th>
<th>Carbohydrate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS-7</td>
<td>8.1**(a)</td>
<td>3.5**(b)</td>
<td>4.0**(a)</td>
<td>12.9**(a)</td>
<td>10.9**(a)</td>
<td>59.7**(a)</td>
</tr>
<tr>
<td>OS-6</td>
<td>6.7**(a)</td>
<td>2.6**(a)</td>
<td>4.6**(a)</td>
<td>13.3**(b)</td>
<td>12.6**(b)</td>
<td>59.9**(a)</td>
</tr>
<tr>
<td>OS-346</td>
<td>8.2**(a)</td>
<td>3.9**(b)</td>
<td>5.3**(a)</td>
<td>13.6**(b)</td>
<td>13.4**(b)</td>
<td>55.7**(b)</td>
</tr>
<tr>
<td>HFO-114</td>
<td>8.0**(a)</td>
<td>3.4**(b)</td>
<td>4.2**(a)</td>
<td>14.4**(c)</td>
<td>12.8**(b)</td>
<td>57.0**(b)</td>
</tr>
<tr>
<td>Kent</td>
<td>7.9**(a)</td>
<td>2.9**(a)</td>
<td>5.1**(b)</td>
<td>13.9**(b)</td>
<td>13.1**(c)</td>
<td>57.4**(b)</td>
</tr>
</tbody>
</table>

Mean followed by the same superscript within the column does not differ significantly \((p < 0.05)\).

Table 3  Functional properties of flours from control and toasted oat from different cultivars.

<table>
<thead>
<tr>
<th>Oat cultivars</th>
<th>WAC (%)</th>
<th>OAC (%)</th>
<th>Foaming capacity (%)</th>
<th>Emulsion activity (%)</th>
<th>Emulsion stability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Control)</td>
<td>(Toasted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS-7</td>
<td>175**(a)</td>
<td>209**(b)</td>
<td>191**(a)</td>
<td>213**(b)</td>
<td>8**(a)</td>
</tr>
<tr>
<td>OS-6</td>
<td>180**(a)</td>
<td>200**(b)</td>
<td>201**(a)</td>
<td>233**(b)</td>
<td>22**(a)</td>
</tr>
<tr>
<td>OS-346</td>
<td>181**(a)</td>
<td>214**(b)</td>
<td>211**(a)</td>
<td>223**(b)</td>
<td>20**(a)</td>
</tr>
<tr>
<td>HFO-114</td>
<td>195**(a)</td>
<td>222**(b)</td>
<td>222**(a)</td>
<td>245**(b)</td>
<td>12**(a)</td>
</tr>
<tr>
<td>Kent</td>
<td>167**(a)</td>
<td>253**(b)</td>
<td>189**(a)</td>
<td>219**(b)</td>
<td>10**(a)</td>
</tr>
</tbody>
</table>

a, b, c, d, and e superscript are significantly \((p < 0.05)\) different column wise within different cultivars and \(p\) and \(q\) superscript are significantly \((p < 0.05)\) different row wise within a cultivar. Subscripts denote the percentage increase \((\%\) from control samples for corresponding properties.

8 and 22 g/100 g. Flour from cv’s OS-6 and OS-346 showed good FC. Flours from different cultivars also differed significantly \((p < 0.05)\) in their abilities to emulsify oil with cv. OS-7 and cv. Kent showing the lowest and the highest values. All flours showed good foam stabilities during 120 min of storage (Fig. 1). Emulsion stabilities of flours ranged from 67.7% to 73.3%, the lowest for cv. OS-6 and the highest for cv. HFO-114 was observed. As foam stability is governed by the ability of the film formed around the entrapped air bubbles to remain intact without draining, it follows that stable foams can only be formed by highly surface-active solutes (Cherry and McWatters, 1981).

3.3. Color characteristics of flour

Hunter color values of flour from control and toasted oat cultivars are shown in Table 4. \(L^*\) value varied significantly \((p < 0.05)\) among flours and ranged from 74.6 to 81.9. Flour from both control and toasted samples of cv.OS-346 was lighter in color in comparison with others. Toasting led to decrease in \(L^*\) value by 0.6-3.6%. \(a^*\) value gives the degree of the redness, with cv.OS-346 showing more \(a^*\) value. Toasting led to increase in \(a^*\) value from 1.5 to 2.1 with % increase from 6.2% to 28.5%. The yellowness \((b^*)\) of flours ranged from 9.3 to 10.6 and upon toasting the yellowness increased by 7.6-25.2%. Flours from cv’s. HFO-114 and OS-346 showed the maximum yellowness after toasting.
Table 4  Color characteristics of flour from control and toasted oat from different cultivars.

<table>
<thead>
<tr>
<th>Oat cultivars</th>
<th>(L^*) (control)</th>
<th>(\Delta L^*) (control)</th>
<th>(a^*) (control)</th>
<th>(\Delta a^*) (control)</th>
<th>(b^*) (control)</th>
<th>(\Delta b^*) (control)</th>
<th>(b^*) (toasted)</th>
<th>(\Delta b^*) (toasted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS-7</td>
<td>75.9</td>
<td>9.5</td>
<td>1.3</td>
<td>1.5</td>
<td>9.7</td>
<td>10.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS-6</td>
<td>74.6</td>
<td>8</td>
<td>1.6</td>
<td>1.8</td>
<td>10.5</td>
<td>11.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS-346</td>
<td>81.9</td>
<td>1.8</td>
<td>1.9</td>
<td>2.1</td>
<td>10.6</td>
<td>11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFO-114</td>
<td>79.3</td>
<td>7.8</td>
<td>1.6</td>
<td>1.7</td>
<td>9.5</td>
<td>11.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kent</td>
<td>78.0</td>
<td>7.7</td>
<td>1.4</td>
<td>1.8</td>
<td>9.3</td>
<td>10.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a, b, c, d, and e superscript are significantly \((p < 0.05)\) different column wise within different cultivars and p and q superscript are significantly \((p < 0.05)\) different row wise within a cultivar. Subscripts denote the percentage increase \((\uparrow)\) or decrease \((\downarrow)\) from control samples for corresponding properties.

3.4. Total phenolic content (TPC) of oat flour

The total phenolic content (TPC) of flour among control oat cultivars varied significantly \((p < 0.05)\) and ranged from 1744 to 2687 \(\mu\text{g GAE/g}\) (Table 5), the highest and the lowest being observed for cv.HFO-114 and cv.OS-346, respectively. Gujral et al. (2011) reported TPC in oat samples in the range from 1754 to 3579 \(\mu\text{g FAE/g}\). Among flours from toasted samples, TPC also differed significantly \((p < 0.05)\) with cv.HFO-114 having the highest value. Toasting increased TPC by 11.5–27.1%, with cv.OS-7 having the maximum increase. The results confirmed previous studies; an increase in phenolic compounds after thermal treatment has been reported by various workers. Pradeep and Guha (2011) suggested increase in TPC during toasting due to the increase in the extractability of bound phenolics by the thermal degradation of cellular constituents. Dewanto et al. (2002) explained that thermal processing might release more bound phenolic acids from the breakdown of cellular constituents. TPC was positively correlated with protein content \((r = 0.836, p < 0.05)\) while upon toasting this correlation decreased \((r = 0.786, p < 0.05)\).

3.5. Antioxidant activity (AOA)

Control oat samples showed AOA in the range from 11.9% to 15.3% (Table 5). Toasting led to significant increase in AOA by 29.1–53.6%, with increase more pronounced for cv.OS-346. Xu et al. (2009) reported increase in DPPH scavenging activity by 82.2% in oats after thermal processing. Several authors claim that higher antioxidant properties of thermally processed foods could be due to the formation of Maillard products such as HMF (5-hydroxymethyl-2-furaldehyde), which render high antioxidant activity (Dueñas et al., 2006; Siddhuraju, 2006). AOA exhibited a positive correlation \((r = 0.931, p < 0.05)\) with TPC, which upon toasting showed a decrease \((r = 0.851, p < 0.05)\). Lahouar et al. (2014) reported a significant positive correlation \((p < 0.01)\) between the TPC and the antioxidant activity (DPPH, \(r = 0.777\)) for diverse varieties of whole oat.

3.6. Metal chelating activity of oat flours

Metal chelating activity is the most commonly used method for the evaluation of antioxidant activities. The metal chelating activity of flour from oat cultivars varied significantly \((p < 0.05)\) and ranged from 28.4% to 46.2%, the highest and the lowest being observed for cv.OS-346 and cv.OS-6, respectively (Table 5). After toasting, the metal chelating activity increased significantly \((p < 0.05)\) for all the cultivars. The increase was 33.9–74.4% in toasted oat flours. Randhir et al. (2008) reported that the increase in metal chelation after thermal processing may be attributed to alteration of phenolic structure and/or degradation of phenolic compounds to different Maillard reaction products like melanoids which could also act as antioxidants. Metal chelating activity was positively correlated with hunter \(L^*\) value \((r = 0.955, p < 0.05)\) which decreased after toasting \((r = 0.782, p < 0.05)\).

Table 5  TPC, AOA, metal chelating activity and TFC of control and toasted oat from different cultivars.

<table>
<thead>
<tr>
<th>Oat cultivars</th>
<th>TPC (\mu\text{g GAE/g}) (control)</th>
<th>TPC (\mu\text{g GAE/g}) (toasted)</th>
<th>AOA (%) (control)</th>
<th>AOA (%) (toasted)</th>
<th>Metal chelating activity (%) (control)</th>
<th>Metal chelating activity (%) (toasted)</th>
<th>TFC (\mu\text{g CE/g}) (control)</th>
<th>TFC (\mu\text{g CE/g}) (toasted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS-7</td>
<td>1844</td>
<td>2345</td>
<td>11.9</td>
<td>17.1</td>
<td>31.3</td>
<td>54.6</td>
<td>499</td>
<td>302</td>
</tr>
<tr>
<td>OS-6</td>
<td>1903</td>
<td>2245</td>
<td>13.4</td>
<td>17.3</td>
<td>28.4</td>
<td>40.3</td>
<td>612</td>
<td>366</td>
</tr>
<tr>
<td>OS-346</td>
<td>1744</td>
<td>2150</td>
<td>12.3</td>
<td>18.9</td>
<td>46.2</td>
<td>61.9</td>
<td>588</td>
<td>412</td>
</tr>
<tr>
<td>HFO-114</td>
<td>2687</td>
<td>2998</td>
<td>15.3</td>
<td>21.4</td>
<td>35.3</td>
<td>54.4</td>
<td>532</td>
<td>401</td>
</tr>
<tr>
<td>Kent</td>
<td>2135</td>
<td>2549</td>
<td>13.9</td>
<td>19.3</td>
<td>33.8</td>
<td>45.6</td>
<td>433</td>
<td>333</td>
</tr>
</tbody>
</table>

a, b, c, d, and e superscript are significantly \((p < 0.05)\) different column wise within different cultivars and p and q superscript are significantly \((p < 0.05)\) different row wise within a cultivar. Subscripts denote the percentage increase \((\uparrow)\) or decrease \((\downarrow)\) from control samples for corresponding properties.

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3.7. Total flavonoids content

Flavonoids have generated interest because of their broad human health promoting effects, most of which are related to their antioxidant properties (Mira et al., 2002) and to synergistic effects with other antioxidants (Filipe et al., 2001). The antioxidant mechanism of flavonoids, may also result from the interactions between flavonoids and metal ions especially iron and copper (Miller et al., 1996; Brown et al., 1998). The total flavonoids content (TFC) of flour from control oat cultivars varied significantly \( p < 0.05 \) and ranged from 433 to 612 \( \mu \)g CE/g. Toasting led to a decrease in TFC by 23–40.1%, with decrease more pronounced in cv. OS-6 and cv. OS-7. Zhu et al. (2010) suggested decrease in TFC during thermal processing due to heat susceptible nature of flavonoids compounds. TFC was positively correlated with hunter \( a^* \) and \( b^* \) value \( (r = 0.709 \) & 0.903, respectively) and correlation increased after toasting with hunter \( a^* \) value \( (r = 0.919, \ p < 0.05) \) whereas reverse was observed with hunter \( b^* \) value which showed a decrease \( (r = 0.468, \ p < 0.05) \).

4. Conclusions

TPC, AOA, MCA, and TFC of control oat cultivars varied from 1744 to 2687 \( \mu \)g GAE/g. 11.9% to 15.3%, 28.4% to 46.2%, and 433 to 612 \( \mu \)g CE/g, respectively. Toasting resulted in an increase in TPC, AOA, and MCA by 11.5% to 27.1%, 29.1% to 53.6%, and 33.9% to 74.4%, respectively, however, the treatment decreased TFC by 23% to 40.1% in flours. Toasting also resulted in significant \( (p < 0.05) \) decrease in physical parameters studied and hunter \( L^* \) value. However, reverse was observed for WAC, OAC, hunter \( a^* \) and \( b^* \) values which showed increase in values after toasting. Thus, oats which are nowadays increasingly used in breakfast cereals and bakery products can be beneficial in their health promoting effects when consumed in a toasted form.

Conflict of interest

The authors declare no conflict of interest.

References


