Nutritional, antioxidant, microstructural and pasting properties of functional pasta

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Received 24 January 2016; revised 5 March 2016; accepted 7 March 2016

Keywords: Pasta; Phenolic content; Antioxidant activity; Nutritional properties; Microstructure

Abstract The present study aimed to characterize millet-pomace based pasta on the basis of functional, morphological, pasting and nutritional properties with control pasta (100% durum semolina). Functional pasta was developed by using blend of 20% finger millet flour, 12% pearl millet flour, 4% carboxy methyl cellulose (CMC) and 64% composite flour containing durum semolina and carrot pomace. Nutritional analysis of developed pasta showed high content of minerals viz calcium, iron, zinc and dietary fiber compared to control pasta. The developed pasta showed better quality characteristics in terms of cooked weight, swelling index and water absorption. Color evaluation of developed pasta showed increase in $L^*$ and $b^*$ values. Phenolic content and antioxidant activity of developed pasta was significantly higher with respect to control. Also significant ($p < 0.05$) variations were observed in pasting properties between pasta samples. Microstructure evaluation of cooked pasta showed better interaction between starch and protein matrix with addition of carboxy methyl cellulose gum.

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1. Introduction

Pasta products are most popular foods. These are normally high in starch but low in dietary fiber, minerals, vitamins and phenolic compounds. In order to enhance nutritional value of pasta several studies have focused on possibility of adding functional ingredients into pasta (Bustos et al., 2013; Fiorda et al., 2013). Millets are rich in phytochemicals which exhibit antioxidant and free-radical scavenging activity. These have been shown to impart antimutagenic, antiglycemic and antioxidative properties (Dykes and Rooney, 2006). As these are also “gluten-free” it could be suitable for persons suffering from celiac disease (gluten intolerance). Having several health benefits there is great interest for millets among scientists in their use for different food formulations. Pearl millet (Pennisetum typhoides) is one of the most important drought tolerant crops cultivated mostly in semi-arid parts of Africa and Asia. Besides being rich in iron, calcium, zinc, it is nutritionally comparable and even superior to major cereals due to its energy and protein value (Sehgal and Kwatra, 2006; Malik et al.,...
Finger millet (*Eleusine coracana*) is widely grown minor millet in the world. It is a rich source of calcium and dietary fiber. Its seed coat is an edible component of kernel and rich source of phytochemicals such as polyphenols. It can be used both in the native and in the processed forms (Rao and Muralikrishna, 2001). Carrot (*Daucus carota*) is an excellent source of calcium pectate (pectin fiber). Its pomace is a natural source of α-carotene and β-carotene. Besides this carrot pomace is having good residual amount of vitamins, minerals and dietary fiber. Incorporation of pomace into extruded products could provide dietary fiber source. Also addition of dietary fiber can reduce the glycemic index of pasta and introduce additional health benefits. With an increasing concern by health conscious people more nutritious pasta products rich in minerals, phenolic compounds and dietary fiber with low glycemic index have become the subject of primary significance. In our previous study it was observed that incorporation of millet flours and carrot pomace into pasta at higher levels does not show better pasta cooking quality characteristics, so there is need of addition of hydrocolloid. Thus the present study aimed to develop functional pasta from blends of millet flours and carrot pomace and to study the quality characteristics of developed functional pasta.

2. Material and methods

Durum wheat semolina was procured from Goyal Wheat Milling Industries, Indore (India). Finger millet and Pearl millet grains (HHB-67) were obtained from Shimla (India) and Hisar (India). Finger and pearl millet flour and carrot pomace were prepared as per method used by Gull et al. (2015a). Carboxy methyl cellulose was procured from Loba Chemie Pvt. Ltd. (Mumbai). All the chemicals used for analysis were of analytical grade.

2.1. Preparation of pasta

From the previous experiments of Gull et al. (2015b) results not shown here, blend of 20 g FMF and 12 g PMF 100 g⁻¹ to composite flour (96 g durum wheat semolina: 4 g carrot pomace) was optimized. The optimized formulation was added with hydrocolloid such as carboxy methyl cellulose (4 g–100 g⁻¹) to improve the quality of developed pasta. Blend of different flours was mixed in Hobart mixer (model 5KPM50, USA) at slow speed (set 1) with optimal (34.71 ml) water for 12–15 min. Finally premixed dough was extruded using pasta machine with single screw (Model: Dolly La Monferrina, Italy) fitted with an adjustable die. Finally extruded pasta was dried at 60 °C for about 3 h. The resultant dried pasta was packed in Low density polyethylene (LDPE) bags kept in refrigerator for further analysis.

2.2. Proximate and mineral analysis of pasta sample

Moisture, protein, fat and ash contents of pasta samples were determined using AACC method (2000). Carbohydrate was calculated by subtracting the sum of moisture, protein, fat and ash from 100. Minerals were determined using the method of Chapman and Pratt (1982). Total dietary fiber content was analyzed by using the method of IS-11062 (1984). Carotene content was determined by using the method of Ranganna (1986).

2.3. Cooking characteristics of pasta

Cooking quality characteristics of pasta viz, cooking loss and cooked weight were determined according to AACC approved method (2000).

2.4. Swelling index and water absorption

Swelling index and water absorption index of cooked pasta were measured by using the method described by Tudorica et al. (2002).

Swelling index of cooked pasta (g of water per g of dry pasta) was evaluated by drying pasta samples to constant weight at 105 °C and expressed as follows:

\[
\text{Weight of cooked product - weight after drying} \times 100 \quad (1)
\]

\[
\text{Weight of cooked pasta - weight after drying} \quad (2)
\]

2.5. Pasta firmness

The firmness of cooked pasta samples was measured by using a Texture Analyzer model (TA-XT2., Stable Micro systems, UK). Three cooked pasta strands were sheared at a 90° angle. The shear was performed using a probe (75 mm diameter) at a crosshead speed of 50 mm/min and load cell 50 N. The force required to shear the pasta was measured.

2.6. Extraction and determination of total phenolics content and antioxidant activity

Samples were extracted using the method of Abu Bakar et al. (2009) with slight modification. Briefly 2 g raw and 5 g cooked pasta were extracted for 2 h with 10 ml of 80% methanol at 28 °C on an orbital shaker set at 180 rpm. The mixture was centrifuged (Rota 4R-V/Fm) at 1400 g for 20 min and the supernatant was decanted. The sediment was re-extracted under identical conditions. The supernatant was combined and used for the total antioxidant activity and total phenolics.

Antioxidant activity was measured using the method described by Brand-Williams et al. (1995). The supernatant 0.1 ml was reacted with 3.9 ml of a 6 × 10⁻³ mol/l of DPPH solution. The absorbance at 515 nm was read at 0 and 30 min using a methanol blank. The antioxidant activity was calculated as % discoloration:

\[
\left\{1 - \frac{A \text{ of sample } t = 30}{A \text{ of control } t = 0}\right\} \times 100 \quad (3)
\]

The total phenolic content (TPC) was determined by Folin–Ciocalteu spectrophotometric method as described by Sharma and Gujral (2010). About 0.15 ml Folin–Ciocalteu reagent was added to the extract (0.3 ml of aliquot). The mixture was set aside to equilibrate for 5 min and then mixed with 0.3 ml of 7% sodium carbonate. Subsequent incubation was at 25 °C temperature for 90 min, and the absorbance of the mixture
was read at 725 nm (HACH, DR-6000, Germany). Methanol was used as a blank. The results were expressed as mg of Gallic acid equivalents (GAE) per gram of sample.

2.7. Pasting properties

The pasting properties of pasta samples were measured with a Rapid-Visco Analyzer (RVA Pertin). Ground pasta (3.5 g) was added to 25 ml of distilled water and mixed in an RVA canister. The temperature profile used was based on that of Bruneel et al. (2010) and included a temperature holding step (1 min at 50 °C), a linear temperature increase to 95 °C at 7.5 °C/min, a holding step (8 min at 95 °C), a linear temperature decrease to 50 °C at 7.5 °C/min and a final isothermal step at 50 °C (10 min). The paddle speed was 960 rpm for the first 7 s and then 160 rpm. The parameters measured were peak viscosity, i.e. the maximum viscosity during the cycle and a measure of shear resistance of particles, and end viscosity (eP), i.e. the viscosity at the end of the run (31 min); breakdown is the difference between peak and trough; setback is the difference between final and trough. Three replicate runs were run for each sample and the mean values are presented.

2.8. Color evaluation

Color of both uncooked and cooked pasta samples was determined using a colorimeter (Model CR-10, Konica Minolta Sensing, Inc., Japan) equipped with D65 illuminant. Measurements were made at random locations on the surface of uncooked and cooked pasta. Lightness (L*), redness (a*) and blueness (b*) values were noted.

2.9. Scanning electron microscopy

Uncooked and cooked freeze-dried pasta were taken and cut transversally with a sharp blade without damaging the structure. The cross section of the uncooked and cooked freeze-dried samples was mounted on the specimen holder and sputter-coated with gold (2 min, 2 mbar). Finally, each sample was transferred to the microscope where it was observed at 15 kV and a vacuum of 9.75 × 10⁻⁵ torr. A Leo scanning electron microscope (model 6510 LV, Leo Electronic Systems, Cambridge, UK) was used to scan the images.

2.10. Statistical analysis

The experiments were carried out in triplicate. The significant differences were obtained by one-way analysis of variance (ANOVA) followed by Duncan’s multiple range test (p < 0.05) using Statistica V.7.

3. Result and discussion

3.1. Chemical analysis of pasta

The results of nutritional analysis of millet-pomace based pasta and control pasta are shown in Table 1. Non significant (p < 0.05) difference was observed in moisture content between pasta samples. Protein, fat and ash contents of samples ranged from 10.16 to 11.60%, 1.6 to 0.60%, and 0.40 to 0.80% respectively, while crude fiber content differs significantly (p < 0.05) as shown in Table 1. Carbohydrate content and energy value of developed functional pasta were high compared to control. Dietary fiber content ranges from 8.47 to 16.71%. Minerals viz, calcium, iron and zinc content of developed millet-pomace based pasta increased with respect to control. This increase in mineral content could be due to addition of millet flours and carrot pomace. Carotenoid content of pasta samples differs significantly (p < 0.05) as shown in Table 1. This difference in carotene content could be due to addition of carrot pomace to the developed functional pasta.

3.2. Cooking characteristics of pasta

Pasta cooking quality characteristics such as cooking loss, cooked weight, swelling index and water absorption are presented in Table 2. Low amount of residue in cooked water is desirable for high quality pasta. Because during cooking soluble starch and other soluble components including non-starch polysaccharides leach out into water and as a result the cooked water becomes thick. As indicated in Table 2, solid loss of developed millet-pomace based functional pasta decreased significantly (p < 0.05) with respect to control. This decrease in cooking loss could be attributed due to addition of carboxy methyl cellulose which improved the gluten network and forms a matrix with the gluten proteins where starch granules get embedded and lessen the solid loss. Cooked weight of developed functional pasta increased significantly (p < 0.05) compared to control. This increase in cooked weight may be due to water binding and water holding capacity of carboxy methyl cellulose and pomace. Susanna and Prabhasankar (2013) also reported increase in cooked weight in addition to guar gum to pasta. Swelling index of pasta is an indicator of water absorbed by the starch and proteins during cooking which is utilized for the starch gelatinization and protein hydration. Results shown in Table 2 indicate that swelling index and water absorption (%) of developed functional pasta increased with respect to control. This may be because the

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Table 1  Nutritional composition of pasta products (per 100 g).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Millet-pomace based pasta</th>
<th>Durum semolina pasta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (g)</td>
<td>9.00 ± 0.61a</td>
<td>8.90 ± 0.96b</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>10.16 ± 0.85a</td>
<td>11.60 ± 0.51a</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>6.00 ± 0.42a</td>
<td>1.60 ± 0.05b</td>
</tr>
<tr>
<td>Ash (g)</td>
<td>0.80 ± 0.05a</td>
<td>0.40 ± 0.03a</td>
</tr>
<tr>
<td>Fiber (g)</td>
<td>3.20 ± 0.24a</td>
<td>2.30 ± 0.10a</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>70.84 ± 1.18b</td>
<td>75.20 ± 1.14a</td>
</tr>
<tr>
<td>Energy value (kcal)</td>
<td>378 ± 3.46a</td>
<td>356.80 ± 3.00b</td>
</tr>
<tr>
<td>Dietary fiber (g)</td>
<td>16.71 ± 0.25a</td>
<td>8.46 ± 0.41a</td>
</tr>
<tr>
<td>Soluble (g)</td>
<td>1.36 ± 0.03a</td>
<td>1.25 ± 0.06b</td>
</tr>
<tr>
<td>Insoluble (g)</td>
<td>15.35 ± 0.26b</td>
<td>7.21 ± 0.16a</td>
</tr>
<tr>
<td>Ca (mg)</td>
<td>42.33 ± 1.27b</td>
<td>21.74 ± 1.09a</td>
</tr>
<tr>
<td>Fe (mg)</td>
<td>42.93 ± 2.63a</td>
<td>30.55 ± 1.24a</td>
</tr>
<tr>
<td>Zn (mg)</td>
<td>15.82 ± 1.60a</td>
<td>12.70 ± 1.10b</td>
</tr>
<tr>
<td>Total carotenes (μg)</td>
<td>2.10 ± 0.10a</td>
<td>1.15 ± 0.06b</td>
</tr>
</tbody>
</table>

Results are expressed as mean values ± standard deviations. Means with same superscripts in a row are not significantly different (p < 0.05) as assessed by Duncan’s multiple range test.
carboxyl and hydroxyl groups in the structure of gum allow them to bind with readily available water thus resulting in an increment in swelling index and water absorption. Pasta textural characteristics are recognized as more important for consumers (Brennan and Tudorica, 2007). This is one of the critical aspects for quality assessment of pasta. In our study the firmness value of developed functional pasta increased compared to control pasta (Table 2). This increase in firmness of cooked pasta samples could be due to addition of additives (Rajeshwari et al., 2013). Sensory evaluation revealed non-significant difference ($p < 0.05$) in overall acceptability between pasta samples.

### 3.3. Total phenolic content and Antioxidant activity of flours and pasta samples

DPPH is an effective method generally used to persuade antioxidant activity (Scherer and Godoy, 2009). It is based on hydrogen donation ability and has desirable correlation with other procedure. Plant extracts that present antioxidant activity (OAA) values lower than 0.5 can be considered weak antioxidants. Thus all flours and pasta samples are having strong antioxidant activity (Table 3). Phenolic compound rich foods have been shown to possess antioxidant properties. Millets contain phytochemicals that may provide beneficial health effects other than basic nutrients. Total phenolic content and antioxidant activity of flours and pasta samples before and after cooking are presented in Table 2. The total phenolic content of millet flours (finger and pearl millet) were significantly different ($p < 0.05$) than carrot pomace and durum semolina. The results indicate that incorporation of millet flours in pasta could be a feasible way to distribute this phenolic-rich product.

### 3.4. Pasting properties of pasta flours

The pasting properties of pasta flours are presented in Table 4. Significant differences ($p < 0.05$) were observed in pasting behavior of two pasta samples. Addition of carboxymethyl cellulose gum to millet pomace based pasta caused increase in peak viscosity (PV) and breakdown viscosity (BV), but led to decrease in setback viscosity (SV) compared to control (durum semolina) pasta. Peak viscosity reflects the ability of starch granules to swell freely before their physical breakdown. Hence addition of gum (carboxy methyl cellulose) to developed millet-pomace based pasta promotes an increment in peak viscosity (PV). The results suggest that addition of carboxymethyl cellulose gum could assist swelling of starch based pasta could be due to addition of millet flours, as these are known to be potent source of antioxidant compounds (Sripriya et al., 1996). As shown in Table 3, antioxidant activity of cooked pasta samples decreased significantly due to thermal degradation during cooking thus resulting in loss of antioxidant activity (Anna et al., 2014). The results indicate that incorporation of millet flours in pasta could be a feasible way to distribute this phenolic-rich product.

### Table 2 Cooking quality characteristics of pasta samples.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Durum semolina pasta</th>
<th>Millet-pomace based pasta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal cooking time (min)</td>
<td>7.00 ± 0.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.00 ± 0.12&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooking weight (g/10 g)</td>
<td>33.93 ± 1.28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35.10 ± 1.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooking loss (%)</td>
<td>7.66 ± 0.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.10 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Swelling index</td>
<td>1.92 ± 0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.58 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>181 ± 3.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>202 ± 2.40&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Firmness (N)</td>
<td>5.94 ± 0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.50 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>OAA (overall acceptability)</td>
<td>8.6 ± 0.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.36 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Results are expressed as mean values ± standard deviations. Means with same superscripts in a row are not significantly different ($p < 0.05$) as assessed by Duncan’s multiple range test.

### Table 3 Total phenolic content and antioxidant activity of flours and pasta samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total phenolic content (mg gallic acid/g)</th>
<th>DPPH activity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Flour samples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finger millet flour</td>
<td>0.36 ± 0.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>26.4 ± 2.46&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pearl millet flour</td>
<td>0.44 ± 0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.8 ± 2.19&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Durum semolina</td>
<td>0.23 ± 0.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>11.54 ± 1.32&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carrot pomace</td>
<td>0.25 ± 0.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.8 ± 0.92&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>(B) Pasta samples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncooked control pasta</td>
<td>0.22 ± 0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.54 ± 0.43&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooked control pasta</td>
<td>0.09 ± 0.07&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.59 ± 0.72&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Uncooked millet-pomace</td>
<td>0.67 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.45 ± 2.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>based pasta</td>
<td>0.30 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.80 ± 0.90&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± standard deviation. Means in the same column of either section (A) or section (B) with different letters are significantly different ($p < 0.05$), as assessed by Duncan’s multiple range test.

### Table 4 Pasting properties of uncooked pasta samples.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Pasting temperature (°C)</th>
<th>Peak viscosity (cP)</th>
<th>Breakdown viscosity (cP)</th>
<th>Setback viscosity (cP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durum semolina pasta</td>
<td>92.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>915&lt;sup&gt;b&lt;/sup&gt;</td>
<td>104&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1874&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Millet-pomace based pasta</td>
<td>88.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>932&lt;sup&gt;a&lt;/sup&gt;</td>
<td>299&lt;sup&gt;a&lt;/sup&gt;</td>
<td>788&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Results are expressed as means. Means with same superscripts in a column are not significantly different ($p < 0.05$) as assessed by Duncan’s multiple range test.
### Table 5  
Color analysis of uncooked and cooked pasta samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Uncooked</th>
<th>Cooked</th>
<th>Uncooked</th>
<th>Cooked</th>
<th>Uncooked</th>
<th>Cooked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durum semolina pasta</td>
<td>51.37 ± 1.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>57.19 ± 0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.39 ± 0.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.64 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.23 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.81 ± 0.54&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Millet-pomace based pasta</td>
<td>36.84 ± 1.72&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46.09 ± 0.90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.90 ± 0.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.78 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.90 ± 1.34&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.85 ± 0.65&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± standard deviation. Means with same superscripts in a column are not significantly different (p < 0.05) as assessed by Duncan’s multiple range test.

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**Figure 1**  
Microstructure of transverse sections of uncooked and cooked pasta samples.  
(a) Uncooked durum semolina pasta.  
(b) Uncooked millet and carrot pomace based pasta.  
(c) Cooked durum semolina.  
(d) Cooked millet and carrot pomace based pasta; PES – protein embedded starch.
granules as peak viscosity shifts to high value from 915 to 932 cP. The lower peak viscosity value of 915 cP in control pasta may be due to its higher protein content. Stability of hot starch pastes is described by breakdown viscosity (BV). With addition of carboxymethyl cellulose gum, stability of developed millet-pomace based pasta increased as shown by its breakdown value of 299 cP than control (durum semolina) pasta which showed only breakdown value of 104 cP. Setback viscosity is related to retrogradation and reordering of starch molecules. Low setback values indicate low rate of starch retrogradation and syneresis. As indicated in Table 4 Setback value (SV) of pasta samples differs significantly (*p < 0.05). This indicates that addition of carboxymethyl cellulose can improve the quality of pasta as it shows low setback value of 788 cP compared to control (durum semolina) pasta (1874 cP).

3.5. Color analysis

Color is an important factor for assessing the visual quality and market value of food products. Color values were measured for both cooked and uncooked pasta samples. Uncooked control (durum semolina) pasta showed highest lightness \( L^* \) value (51.37) followed by millet-pomace based pasta (36.84). Pasta samples after cooking showed an increase in \( L^* \) value (Table 5) and this increase in lightness may be due to color loss during cooking. Uncooked millet-pomace based pasta showed highest \( a^* \) value (3.90) compared to control (durum semolina) pasta (0.39). This could be due to the brick red seed coat color of finger millet flour. Cooked millet-pomace based pasta showed increase in yellowness \( b^* \) value (9.9–11.85) Table 5. This may be due to water soluble nature of carotenoids present in carrot pomace. Such color changes in pasta samples could be due to swelling and conversion of pigments during cooking.

3.6. Scanning electron microscopic (SEM) studies of pasta samples

Scanning electron microscopy (SEM) shows arrangement of starch granules and gluten network in pasta. Scanning electron microscopic (SEM) studies were carried out using dry and freeze dried pasta samples. As shown in Fig. 1(a and b) numerous starch granules were visible on the surface of uncooked pasta samples. However both cooked pasta samples presented a smooth outer surface in which starch granules are completely embedded in protein matrix (Fig. 1c and d). This may be because of cooking as pasta strands expand in volume during cooking and as a result great deal of stress was imparted on the enveloping protein film; thus, surface of pasta samples becomes smooth. It is also evident from cooked pasta micrograph images which show better protein starch network. Hence overall carboxy methyl cellulose inclusion into millet-pomace based pasta encapsulates the starch granules and thus reduces the leaching of starch upon cooking. This is also well supported by results of cooking loss as millet-pomace based pasta was having significantly (*p < 0.05) lower cooking loss. Smooth and intact microstructure with addition of xanthan gum in gluten free pasta was also observed by Susanna and Prabhansankar (2013). Similarly Rajeshwari et al. (2013) also reported that starch granules are tightly bound in gluten network with addition of gum Arabica in onion based pasta.

4. Conclusion

Millets and carrot pomace being rich in phytochemicals, minerals and dietary fiber, incorporation of these into pasta products will add health benefits. As consumption of pasta is becoming popular worldwide, this kind of pasta will supply essential nutrition as well as health benefits. Minerals viz; calcium, iron and zinc of developed millet-pomace based pasta were significantly higher than control pasta. Pasting properties of pasta samples differ significantly. Addition of carboxymethyl cellulose gum to developed millet pomace based functional pasta showed better cooking quality attributes such as cooked weight, swelling index and water absorption. The developed functional pasta showed increase in phenolic content and antioxidant activity. But this content decreased slightly after cooking. Thus it could be concluded that good quality nutrient rich pasta can be prepared from blend of millet flours and carrot pomace.

Conflict of interest

None.

Acknowledgments

The first author thanks UGC New Delhi for the grant of (MANF) junior research fellowship to carry out this research work.

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