Influence of die size and drying temperature on quality of pearl millet based pasta

Kirti Jalgaonkar, SK Jha and Manoj Kumar Mahawar

Abstract
An innovative approach is proposed to study the influence of die size and drying temperature on the quality characteristics of pasta made from blend of wheat semolina and pearl millet flour in the ratio of 50:50 having particle size of 425 μm. Initially, pasta of wall thickness 0.49, 0.91 and 1.33 mm was prepared and submitted to cooking time, cooking loss and textural properties. Observation indicated that pasta with wall thickness of 1.33 mm had poor cooking stability, texture and surface stickiness property than 0.91 mm and 0.49 mm thickness pasta. Pasta of 0.91 mm thickness had least cooking loss, cooking time and good textural properties. Further, quality of pasta dried at different drying temperature (50, 60, 70, 80, 90°C) was studied in terms of colour, cooking loss and hardness. L values (lightness) ranged from 39.89 to 31.13, decreasing (becoming darker) with increased drying temperature. Hardness for cooked pasta ranged from 10.58 to 13.06 N, with higher values for pasta dried at 90°C. Cooking loss ranged from 9.17 to 8.48 %. However, drying temperature showed non-significant (p>0.05) effect on cooking loss. Results pointed out that pasta dried at 50°C was lighter in colour, good texture and minimum cooking loss than the pasta dried at higher temperatures.

Keywords: pasta, pearl millet flour, die size, drying temperature

Introduction
The principal raw material for preparing pasta of premium quality is 100% durum wheat semolina. Recently, the production of dried pasta from a mixture of semolina and other flours such as wheat flour, whole wheat flour, bran-semolina, corn, rice, oat, legumes, millet flour and so on, is progressively increasing. The main reason for such replacement are, lower availability of semolina in some parts of the world, production of unique kind of pasta with other flours, the elimination of gluten for special diet products, and the increase of nutritional benefits of enriched pasta (Marti et al., 2014) [22]. Therefore in the present study, non-traditional raw material such as pearl millet (Pennisetum glaucum), gluten free grain, was used for preparation of pasta. Pearl millet is a coarse cereal grain with high levels of calcium, iron, zinc, lipids, and proteins (Jalgaonkar and Jha, 2016) [16]. Pearl millet flour has short shelf life of 5 to 10 days (Jalgaonkar et al., 2016; Tiwari et al., 2014) [17, 28]. Also, it is quite difficult to produce pasta from 100% pearl millet flour as these disintegrated after cooking. Hence, blend composition (wheat semolina: pearl millet flour) in the ratio of 50:50 could be used to make pasta with acceptable quality (Jalgaonkar and Jha, 2016) [16]. The prepared pasta could be safely stored in biaxially oriented polypropylene packaging material for 6 months at ambient condition without undue effect on its quality characteristics (cooking quality, textural quality, sensory quality, microbial load) (Jalgaonkar et al., 2017) [15].

The utilization of such non-traditional ingredients for pasta making necessitates the optimization of process parameters, most importantly the drying temperature. During drying, moisture content of product is reduced to around 12.5% in order to allow a long shelf life, translucent appearance and retention of shape. When drying is slow, pasta products tend to spoil or become moldy, but when the drying is rapid, moisture gradients occur resulting in hard surface that cause the products to crack or check, resulting in weak structure which may rise to breakage of the product during packaging and handling, negatively affecting pasta quality (Feillet and Dexter, 1996) [11]. Better results could be obtained by application of low temperature drying (<55°C) to reduce the moisture content of pasta, followed by a high temperature drying (>60°C). Increasing drying temperature at the moisture below 16-18%, resulted in good quality pasta (Resmini and Pagani, 1983) [27].
High temperature drying may lead to excessive swelling of starch granules with the consequent rupture of protein network and the deterioration of cooking quality of pasta (Resmini et al., 1988) [20]. D’Egidio et al. (1990) [9] pointed out some benefits of high temperature drying (>60°C) of pasta viz. reduced cooking loss, decreased surface stickiness, higher firmness and tolerance to over-cooking. However, application of higher drying temperature promoted the occurrence of Maillard reaction, leading to unacceptable brownish colour and lowering of the availability of lysine content in pasta (Petitot et al., 2010) [24].

The prime role of die holes is to provide desired shape and size to pasta (Pollini et al., 2012) [25]. Pasta dimensions, extrusion pressure and the surface condition get affected by the type and condition of die (Maldari and Maldari, 1993) [19] and hence affect the product quality. Pasta made from pearl millet is a growing market but little information is available on optimal drying conditions. In the present work, a novel approach to evaluate the effect of die size as well as drying temperature on cooking and textural quality of pearl millet based pasta has been described.

Materials and Methods
Pasta preparation
Pasta was prepared using a mixture of wheat semolina (WS) and pearl millet flour (PMF) in the ratio of 50:50 having particle of 425 μm (Jalgaonkar and Jha, 2016) [17] were processed in twin screw extruder (BTPL make, Kolkata, India) under the following operating conditions: feed moisture content 30% w.b.; barrel temperature 70°C; feeder speed 12 rpm; screw speed:feeder speed 10 (Jalgaonkar et al., 2018) [14]. Die determines the shape of the product and the pressure inside the barrel and affects the product quality. Hence, suitability of the die was studied initially. The cylindrical hollow shape of pasta was made with a special die where a pin was suspended in the die hole from the back side. Dough, which was forced through the die, flowed around the supports of the pin and then recombined in the annulus between the central pin and the die chamber so that a smooth, round and hollow tube emerged from the die. Three different pins of diameter 6.72 mm, 5.88 mm and 5.04 mm were fitted in the die hole of diameter 7.69 mm. Thus, the pasta obtained through this die assembly had hollow cylindrical shape with different wall thickness of 0.49 mm, 0.91 mm and 1.33 mm. Quality parameters and post-cooking stability of pasta were determined to ascertain the suitability of the die. Since pasta obtained after extrusion had high moisture content, drying was essential. Therefore, drying temperature appropriate for this purpose was standardized. Drying of pasta was carried out in tray dryer (MSW-216, Macro Scientific Works, New Delhi) using five different drying conditions (50, 60, 70, 80, and 90°C). The drying was continued till the pasta achieved 8-9% moisture content. Suitability of the temperature was determined through the quality parameters of the pasta.

Quality evaluation of pasta
Chemical analysis
Moisture (Method 925.10), protein (Method 960.52), ash (Method 923.03) and fat content (ether extract, Method 920.85) of wheat semolina and pearl millet flour was determined using Association of Official Analytical Chemists (AOAC, 1990) [5]. Carbohydrate was calculated by subtracting the sum of moisture, protein, ash and fat from 100 (Merrill and Watt, 1973) [23]. The iron and zinc contents of the samples were estimated using the respective standard curve prepared for each element (AACC, 2003 Method 40-70) [1] and absorbance was read in atomic absorption spectrophotometer (ZEnit-700, USA).

Cooking time
Cooking time is the minimum time necessary for starch gelatinization. It was assessed by pressing cooked pasta between two glass plates and measuring the time for the white core to disappear (Abecassis et al., 1994) [2].

Cooking loss
BIS method [BIS: 1485-(2010)] [7] was used to determine the cooking loss. Ten grams of pasta were cooked in 200 ml of boiling water stirring. After cooking, the sample was rinsed with a stream of water (around 50 ml) for about 30 s in a funnel. Water was allowed to drain for 2 min. The total volume of gruel and the rinsed water collected was measured. 20 ml of the gruel was pipette out after stirring to give even distribution of solid content into a tarred petri dish. The petri dish was then transferred to hot air oven maintained at 105°C and sample was dried to constant mass. It was calculated using Eq. 1.

\[
\text{Cooking loss} \%(\%) = \frac{(M_1 - M) \times V \times 100}{20 \times \text{Weight of uncooked pasta}}
\] (1)

Where, M = mass in grams of petri dish with total dry solids, M = mass in grams of empty petri dish, V = total volume of gruel in ml

Hardness and chewiness
A texture profile analysis (TPA) of pasta was conducted to determine hardness and chewiness of cooked pasta using Texture Analyser (Model: TA+HD®, Stable Micro Systems, UK) using settings viz. pre-test speed: 3 mm/s; test speed: 1 mm/s; post-test speed: 10 mm/s; distance: 50% in compression mode; time: 1 s; data acquisition rate: 200 pps with cylindrical probe (p/75 mm). From the TPA curve as shown in Fig. 1, hardness and chewiness of cooked pasta were calculated as suggested by Limroongreungrat and Huang (2007) [18].
Colours were measured using Hunter colour lab (Model: LX16244, Hunter associate Laboratory, Virginia). Dry pasta samples (10-12g) were placed in the sample cup covered with lid for measurement. Colour values were recorded as ‘L*’ (lightness), ‘a*’ (redness and greenness) and ‘b*’ (yellowness and blueness).

Statistical analysis

The general linear models (GLM) procedure was used for data analysis by taking ten replications for all the experiments. Where significant differences were found, means were separated using the least significant difference using Statistical Analysis Software (SAS) version 9.3. Significance was accepted at \( p<0.05 \).

Results and Discussion

Proximate composition of wheat semolina and pearl millet flour

The proximate composition of WS and PMF of particle size 425 µm used for preparation of pasta is shown in Table 1. The protein, ash, fat, iron and zinc content were found to be higher in PMF than WS, while WS contained higher carbohydrate content than that of PMF.

Table 1: Proximate composition of PMF and WS of particle size 425 µm

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Composition</th>
<th>WS</th>
<th>PMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Moisture content (% w.b.)</td>
<td>10.49±0.02</td>
<td>10.48±0.05</td>
</tr>
<tr>
<td>2.</td>
<td>Protein (%)</td>
<td>10.06±0.05</td>
<td>11.90±0.01</td>
</tr>
<tr>
<td>3.</td>
<td>Ash (%)</td>
<td>0.47±0.01</td>
<td>1.16±0.02</td>
</tr>
<tr>
<td>4.</td>
<td>Fat (%)</td>
<td>0.99±0.03</td>
<td>4.28±0.03</td>
</tr>
<tr>
<td>5.</td>
<td>Carbohydrates (%)</td>
<td>77.99±0.02</td>
<td>72.18±0.03</td>
</tr>
<tr>
<td>6.</td>
<td>Iron (mg/100g)</td>
<td>0.98±0.02</td>
<td>8.92±0.02</td>
</tr>
<tr>
<td>7.</td>
<td>Zinc (mg/100g)</td>
<td>0.12±0.02</td>
<td>2.89±0.01</td>
</tr>
</tbody>
</table>

Notes: Values are mean ±SE of ten replications

Effect of die size on pasta quality and stability

Cooking time (CT) and Cooking loss (CL)

Variation in the die size changed the thickness of pasta. The wall thickness had significant \( (p<0.05) \) effect on CL and CT (Table 2). It was also observed that pasta with smaller thickness required less time to cook and vice versa. Table 2 showed that it takes 5.93 min for cooking of 0.49 mm wall thickness of pasta followed by 8.01 min for 0.91 mm and 16.69 min for 1.33 mm, respectively.

However, non-significant difference \( (p>0.05) \) in CL and CT was found between pasta made of 0.49 mm and 0.91 mm thickness (Table 2). Pasta of 0.49 mm thickness had CL ≤ 8% as suggested for products like macaroni, spaghetti, vermicelli and egg noodles by the Indian Standard (BIS:1485 2010) \(^7\). However, CL in pasta of thickness 1.33 mm exceeded that critical limit, which could be due to the increase in the die opening area and wall thickness of pasta that further resulted in lowering of friction/shear stress in the extruder. Thus, lesser pressure drop on the die creates faster flow of material which develops improper texture to product after drying and ultimately enhances the loss of solids during cooking. Similarly, Abecassis et al. (1994) \(^2\) reported that increase in the open surface of die affect the surface condition, viscoelasticity of dough and decrease the die pressure.

Table 2: Effect of die size on cooking time, cooking loss, hardness and chewiness of cooked pasta

<table>
<thead>
<tr>
<th>Pasta thickness (mm)</th>
<th>Cooking time (min)</th>
<th>Cooking loss (%)</th>
<th>Hardness (N)</th>
<th>Chewiness (N.mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.49</td>
<td>5.93±0.35</td>
<td>7.23±0.10</td>
<td>10.94±0.05</td>
<td>5.93±0.19</td>
</tr>
<tr>
<td>0.91</td>
<td>8.01±0.03</td>
<td>8.01±0.03</td>
<td>9.80±0.29</td>
<td>5.78±0.48</td>
</tr>
<tr>
<td>1.33</td>
<td>16.69±0.19</td>
<td>10.01±0.01</td>
<td>5.93±0.19</td>
<td>3.55±0.23</td>
</tr>
<tr>
<td>F value</td>
<td>427.26</td>
<td>311.06</td>
<td>87.00</td>
<td>47.32</td>
</tr>
</tbody>
</table>

\[ \text{Hardness} = \text{Maximum/peak force of first compression} \]
\[ \text{Cohesiveness} = \frac{\text{Area 2 (area under the second peak of compression)}}{\text{Area 1 (area under the first peak of compression)}} \]
\[ \text{Springiness} = \frac{\text{Distance 2 (distance at which a deformed sample went back to its non-deformed condition after the deforming force is removed during the second compression)}}{\text{Chewiness}} \]
Influence of drying temperature on quality of pasta
Pasta obtained after extrusion has high moisture content and hence drying to appropriate moisture content was necessary before storage. Choosing an appropriate temperature for drying of pasta is an important step which determines the final product quality. Pasta dried at 50, 60, 70, 80 and 90°C required 2, 1.67, 1.33, 1.00 and 0.83 h, respectively of drying time to reach the desired moisture content (8-9% w.b).

Colour
Colour of dry pasta was significantly ($p<0.05$) affected by drying temperature. An increase in drying temperature from 50 to 90°C resulted in deterioration of pasta colour. Table 3 shows that L* (lightness) and b* value (yellowness) of pasta decreased from 39.89 to 31.13 and 17.21 to 14.44, respectively, whereas a* value (redness) increased from 0.71 to 2.50 with increase in the drying temperature from 50-90°C. Pasta dried at low temperature (50°C) was brighter than dried at higher temperature (90°C).

Similarly, Ansari et al. (2013) \[21\] reported that L* value of 20% defatted soy fortified spaghetti dried at 70°C (51.86) was lower than 52°C (52.27) which might be due to the exposure of higher heat to the product while drying. Also, occurrence of non-enzymatic browning resulted in reduction of lightness in spaghetti (Acquistucci, 2000; Garcia-Banos et al., 2004) \[3\]. Howard et al. (2011) \[22\] highlighted that L value (58.52) for peanut flour supplemented pasta dried at 88°C was significantly lower than the pasta dried at 60 or 74°C (61.7 and 61.9, respectively).

Table 3: Influence of drying temperature on L*, a* and b* value of dry pasta

<table>
<thead>
<tr>
<th>Drying temperature (°C)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>39.89±0.16</td>
<td>0.71±0.02</td>
<td>17.21±0.10</td>
</tr>
<tr>
<td>60</td>
<td>38.55±0.04</td>
<td>1.72±0.01</td>
<td>16.87±0.01</td>
</tr>
<tr>
<td>70</td>
<td>35.39±0.12</td>
<td>1.78±0.06</td>
<td>15.60±0.04</td>
</tr>
<tr>
<td>80</td>
<td>34.07±0.35</td>
<td>2.05±0.01</td>
<td>15.29±0.02</td>
</tr>
<tr>
<td>90</td>
<td>31.13±0.44</td>
<td>2.50±0.03</td>
<td>14.44±0.15</td>
</tr>
</tbody>
</table>

F value 121.85\[23\] 264.32\[23\] 46.55\[23\]
Error d.f. 36 36 36
Error MS 0.303 0.005 0.029
LSD 1.04 0.13 0.32

High temperature drying of durum wheat spaghetti at low feed moisture content enhanced the browning of pasta (Zweifel et al., 2003) \[20\]. Howard also pointed out that pasta became dark in colour as drying temperature increased from 60 to 88°C. Similarly, brightness of spaghetti made from semolina and semolina added with buckwheat bran flour (10-30%) dried at higher temperature (90°C) was less than dried at lower temperature (40°C) (Manthey et al., 2004) \[21\].

Cooking loss
Cooking loss of pasta varied from 8.48 to 9.17% with variation in drying temperature from 50 to 90°C (Fig. 3).
High CL (9.17%) was observed in pasta dried at 50°C whereas corresponding lower value (8.48%) was observed for pasta dried at 90°C. The reduction of CL with increase in temperature may be due to formation of partial coagulation of gluten structure during high temperature drying leading to minimum loss of starch (Braibanti, 1980) [8]. Similarly, Fang and Khan (1996) [10] found out that increase in drying temperature from 40 to 90°C decreased the CL of elbow macaroni prepared from durum wheat semolina from 6.7 to 5.9%. Manthey and Schorno (2002) [20] highlighted that cooking loss was greater for spaghetti dried at 40°C (6.5%) than at 70°C (5.8%).

![Fig 3: Effect of drying temperature on cooking loss and hardness of cooked pasta](image)

However, from the statistical point of view, this decrease in CL was non-significant (Table 4). Howard et al. (2011) [13] too reported that an increase in temperature from 60 to 88°C resulted in non-significant effect on cooking loss (6.67 to 6.58%) of wheat flour based pasta supplemented with peanut flour (30-50%) and carrageenan (2.4-2.9%).

Table 4: ANOVA for cooking loss and hardness of pasta affected by drying temperature

<table>
<thead>
<tr>
<th>Drying temperature (°C)</th>
<th>Cooking loss (%)</th>
<th>Hardness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F value</td>
<td>1.51[NS]</td>
<td>736.35[^2]</td>
</tr>
<tr>
<td>Error df</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Error MS</td>
<td>0.13</td>
<td>0.005</td>
</tr>
<tr>
<td>LSD</td>
<td>0.63</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Notes: d.f. refers to degrees of freedom; MS refers to mean sum of square; LSD refers to least significance difference; ^Significant; [NS]Non-significant at 5%

Hardness

With the increase in drying temperature, hardness of cooked pasta increased from 10.58 to 13.06 N (Fig. 3). Hardness was found lower (10.58 N) in pasta dried at 50°C whereas corresponding high values (13.06 N) was observed for pasta dried at 90°C. Results suggested that the difference between hardness was small, but the end product firmness was greater when pasta dried at higher temperature rather than dried at lower temperature. High drying temperature strengthens the gluten matrix which provides protection for starch granules for rupturing during cooking (Manthey and Schorno, 2002) [20] which improved the texture of pasta.

Howard et al. (2011) [13] reported that pasta dried at 88°C was significantly firmer (2.13 N) than pasta dried at 60°C (1.55 N). Zweifel et al. (2013) [20] observed that increase in drying temperature from 80 to 100°C increase the firmness of durum wheat pasta. Wheat flour supplemented with 20% defatted soy flour showed lower firmness (1.85 N) at 52°C of drying temperature than drying at 72°C temperature (2.09 N) (Ansari et al., 2013) [4]. Manthey et al. (2004) [21] reported that pasta prepared from semolina and semolina added with buckwheat bran flour (10-30%) dried at higher temperature (90°C) had highest firmness than dried at lower temperature (40°C).

It was inferred from the study that pasta dried at 50°C was lighter in colour and softer in texture. Physical observation showed development of slight cracks in pasta which was dried at higher temperature 80-90°C, which reduced the pasta appearance. Hence, drying of pasta at 50°C for 2 h till moisture content reached to 8-10% was considered appropriate for development of pearl millet based pasta.

Conclusion

Overall results of this investigation indicated that die size significantly affected the pasta stability after cooking. In particular, pasta sample with wall thickness of 1.33 mm required more cooking time, high cooking loss with least hardness and chewiness compared to pasta of 0.49 and 0.91 mm wall thickness. Instead, there was non-significant difference in quality of pasta of 0.49 mm and 0.91 mm wall thickness. Results also suggested that increasing drying temperature for pearl millet based pasta resulted in decreased cooking loss, increased hardness and darker colour in dry pasta. Hence, pearl millet pasta of wall thickness 0.91 mm dried at 50°C for 2 h till moisture content reached to 8-10% was considered optimum.

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References

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