EFFECT OF HEAT MOISTURE TREATMENT ON FUNCTIONAL AND PHYTOCHEMICAL PROPERTIES OF NATIVE AND MODIFIED MILLET FLOURS

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Abstract
Millets are one of the oldest foods known to humans and cultivated since time immemorial. Millets are termed as nutricereals since, they are nutritionally superior to major cereals with respect to protein, energy, vitamins and minerals. The functional properties and phytochemical components of native and modified millet flours were studied. The functional characteristics such as water absorption index (WAI) and water solubility index (WSI) were maximum in native flour than modified millet four. The data projected for water absorption capacity (WAC) and oil absorption capacity (OAC) of modified millet flour was high when compared with native flour. The soluble, insoluble and total dietary fibre content was observed to be high in modified millet flour than native flour. Among the native flours, little millet contained higher proportions of polyphenols (373.67 ± 12.16 mg GAE/100 g), antioxidant activity was 83.27 ± 2.28 mg AAEAA/100g in pearl millet, phytate content was 35.17 ± 0.63 mg/100g in kodo millet (35.17 ± 0.63 mg/100g) and tannin content was 22.67 ± 0.21 mg TAE/100g, respectively in proso millet flour followed by other millet flour.

Key words : Native flour, modified millet flour, functional characteristics, dietary fibre, phytochemical components.

Introduction
Current dietary guidelines focus on lowering dietary fat and increasing complex carbohydrate intake, such as starch and dietary fiber. The dietary fibre and resistant starch of minor millets have been attributed to exhibit hypoglycemic and hypolipidemic effects (Pathak and Srivastava, 1998). Dietary fibers are important for their hypoglycemic effect, hypolipidemic effect: lowering serum cholesterol hence helps in prevention of atherosclerosis, antitoxic effect and anti-cancerous effect. Glycemic index could be attributed to development of resistant starch during heating and cooling cycles. Heating and cooling cycles significantly increased resistant starch fraction in millets. Resistant starch (defined as any starch that escapes digestion in small intestine) was reported to exhibit a wide range of health benefits such as lowering caloric density and low glycemic response. It was also reported to lower digestibility and act as a fecal bulking agent. Resistant starch, an important starch derivative could be obtained by modification of starches. Starch is classified into rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) according to the rate of glucose release and its absorption in the gastrointestinal tract. RDS is the starch fraction that causes a sudden increase in blood glucose level after ingestion and SDS is a starch fraction that is digested completely in the small intestine at a lower rate as compared to RDS. RS is the starch portion that cannot be digested in the small intestine, but is fermented in the large intestine. The health benefits of RS have been reported as prevention of colon cancer, hypoglycemic effects, substrate for growth of the probiotic microorganisms, reduction of gall stone formation, hypocholesterolemic effects, inhibition of fat accumulation, and increased absorption of minerals. The potential health benefits of SDS are linked to a stable glucose metabolism, diabetes management, mental performance and satiety. Slowly digestible starch content was increased by autoclaving cooling cycle method. Slowly digestible starch, an important starch derivative could be obtained by modification of starches.

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Starch modification is a process of altering the starch structure by affecting the hydrogen bond in a controllable manner. Heat moisture treatment (HMT) is one of many physical methods used to modify starch. HMT is a hydrothermal modification method that has commonly been explored to alter the physicochemical, digestibility, and functional properties of starch with minimum effect on the granule structure (Jacobs and Delcour, 1998). Acid modification of starch is a granular modification of the native starch achieved through treatment of starch below its gel point in aqueous acid suspension (Wang and Wang, 2001). An enzymatic modification involves the exposure of starch suspensions to a number of enzymes primarily, including hydrolyzing enzymes that tend to produce highly functional derivatives. The aim of the present study is to modification of starch from the millet by physical modifications and investigating the behavior of the native and modified starches.

Millets contain good sources of dietary fiber, minerals and phytochemicals with antioxidant activity. Phytochemicals (phenolic compounds and phytates) are responsible for higher antioxidant activity in whole grain foods (Sridevi et al., 2008). Millet has been shown to be helpful in type 2 diabetes mellitus, cardiovascular disease and cancer due to its low glycemic index and antioxidant activity (Hathan and Prasanna, 2011). The hypoglycemic effect of millets with their high crude fiber, dietary fibre, antioxidant, low carbohydrate content, low digestibility and also have β-glucans, which are water soluble gums helpful in impairing glucose metabolism (Itagi et al., 2012).

Minor millets like kodo are also described as nutritious millet and have received far less research and development attention than other crops with regard to crop improvement and utilization. It is the main source of protein and minerals in the daily diets of tribal and weaker section living in remote rural areas. Millets including kodo contain water soluble fiber and this property may be utilized for maintaining or lowering blood glucose response among diabetic and CVD patients. Little millet is rich in fibre content when compared to other small millets. Little millet has a significant role in providing nutraceutical components such as phenols, tannins and phytates along with macro and micro-nutrients. Pearl millet is the most widely grown type of millet. Nutritionally, pearl millet is superior to major cereals with reference to energy value, high quality proteins, fat and minerals such as calcium, iron, zinc. Besides, it is also a rich source of dietary fiber and micro nutrients (Anusehgal and Kwatra, 2006; Malik et al., 2002).

**Materials and Methods**

Whole wheat (*Triticum aestivum*), kodo millet (CO 3) (*Paspalum scrobiculatum*), little millet (CO 6) (*Panicum sumatrensis*), pearl millet (COC 9) (*Pennisetum typhoideum*) and proso millet (COPV 5) (*Panicum miliaceum*) were collected from Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu), India.

**Preparation of sample**

Optimization technology for the development of modified flour from millets

To optimize the technology for the development of modified flour to utilize as the functional food ingredient, the physical modification method has been followed.

Physical modification (Autoclaving-Cooling Cycle)

The physical modification (autoclaving - cooling cycle method) technique was used and followed as per the standard Berry (1986) procedure for the preparation of modified starch (kodo millet, little millet, pearl millet and proso millet) with slight modification. The kodo millet and pearl millet grains were cleaned, washed separately and soaked for 2 hours, ground and then it was pressure-cooked at 121°C (15 lb/in²) for one hour in an autoclave. The gelatinized starch mixture was cooled to room temperature and it was frozen at 4°C for 24 hours, which was termed as one cycle. Then, three additional cycles were carried out, followed by cabinet-drying for about 4-6 hours at 40°C according to the respective stachoses and ground into fine particles and packed in air-tight container.

Functional properties of native and modified millet flours

**Water absorption index and water solubility index**

Water absorption index (WAI) and water solubility index (WSI) were studied by the method described by Anderson et al. (1969). Water absorption capacity (WAC) of flours was measured by the centrifugation method described by Sosulski and Garratt (1976). Oil absorption capacity (OAC) of flour was measured by the centrifugation method described by Lin and Humbert (1974).

**Colour value**

Colour value of flour was measured by using Hunter Lab Colorimeter. Hunter lab calorimeter value L*(0=black, 100=white), a*(+value = red, -value = green) and b*(+value = yellow, -value = blue) values were recorded (Hathorn et al., 2008).

**Phytochemical components of dietary fibre**

The soluble, insoluble and dietary fiber was quantified...
by Hellendoorn technique (James and Theander, 1981).

**Phytochemical components**

Total phenols, tannin and phytate contents were determined by the spectrophotometric method of Sadasivam and Manicam (2008). The radical scavenging ability of the sample was tested on the basis of the radical scavenging effect on the DPPH free radical by Goupy et al. (1999).

**Statistical analysis**

The experiments were conducted in triplicates and the data were expressed as mean± standard deviation (S.D).

**Results and Discussion**

**Functional properties of native and modified millet flours**

Water absorption index (WAI), water solubility index (WSI), water absorption capacity (WAC) and oil absorption capacity (OAC) of native flour and modified millet flour were presented in table 1.

**Water Absorption Index (WAI)**

The water absorption index measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. Results showed that the highest WAI was observed in wheat flour (9.10 ± 0.42 g/100g). The WAI was maximum in native flour ranged from 7.40 ± 0.32 to 8.72 ± 0.15 g/100g than modified millet four ranged from 5.24 ± 0.22 to 5.69 ± 0.13 g/100g respectively. Adebowale et al. (2005), similarly reported that the annealing of cassava starch and heat moisture treatment and annealing of red sorghum starch (modification), respectively decreased starch swelling power and increased swelling power as the temperature increased. Similar trend was noted in the present investigation also.

**Water Solubility Index (WSI)**

The water solubility index measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. Results showed that the highest WAI was observed in wheat flour (9.10 ± 0.42 g/100g). The WAI was maximum in native flour ranged from 7.40 ± 0.32 to 8.72 ± 0.15 g/100g than modified millet four ranged from 5.24 ± 0.22 to 5.69 ± 0.13 g/100g respectively. Adebowale et al. (2005), similarly reported that the annealing of cassava starch and heat moisture treatment and annealing of red sorghum starch (modification), respectively decreased starch swelling power and increased swelling power as the temperature increased. Similar trend was noted in the present investigation also.

**Water Absorption Capacity (WAC)**

The data projected for water absorption capacity of modified millet flour was high when compared with native flour. The WAC was maximum in wheat flour (78.80 ± 3.26 ml/100g). The WAC of native flour ranged between 74.08 ± 1.78 and 76.83 ± 3.38 ml/100g. When modification the WAC was observed to be high and it was ranged between 82.07 ± 3.45 and 88.43 ± 3.33 ml/100g, respectively. Water binding capacity of modified starch was highest due to high amylose content of RS3. It is known that amylose has higher water binding capacity than native starch (Zhiqiang et al., 1999).

**Oil Absorption Capacity (WAC)**

The oil absorption capacity was found to be maximum in modified millet flour than native flour. The OAC of wheat flour was 87.27 ± 3.87 ml/100g. in the native flour, the maximum OAC was recorded to be 85.57 ± 3.00 ml in pearl millet flour followed by little millet flour (84.36 ± 3.27 ml), kodo millet flour (74.74 ± 3.00 ml/100g) and proso millet flour (73.58 ± 2.18 ml/100g). Modified millet flour had the highest OAC and the value was 87.45 ± 3.54 in kodo millet flour followed by little millet flour (86.91 ± 2.13ml/100g), proso millet flour (86.64 ± 2.24) and pearl millet flour (85.82 ± 2.32 ml/100g), respectively. Helen (2010) found that the processed (germination and fermentation) finger millet flour also had a higher oil absorption capacity in the range of 74.43-126.38, which was significantly higher than that of controlled flour (71.40). Abulude et al. (2005) also stated that water and oil absorption of finger millet flour increased during germination.

**Colour index of native and modified millet flours**

Table 2 presents the results of the colour index of native and modified millet flour and pulse flour. The varietal differences were observed for various Hunter colour parameters. The colour of starch affects the colour of the finished product. A bright white colour starch is
The L* value was a parameter for characterizing starch colour, its lightness and it was a direct measurement of its whiteness. The L* value close to 100 indicates whiteness. The chromaticity coordinate a*, which ranges from -60 (green) to +60 (red), the chromaticity coordinate b*, which ranges from -60 (blue) to +60 (yellow), indicated a higher intensity of yellow.

Colour changes gives information about the extent of browning reactions such as caramalization, maillard reaction, degree of cooking and pigment degradation that take place during the starch extraction process (Altan et al., 2008).

The modification of millet flour showed the highest values for the luminosity parameter L* value, Chroma a* values and b* values than native flour. The colour of L*, a* and b* value was 129.53 ± 5.49, 5.52 ± 0.01 and 29.48 ± 0.89 in wheat flour. The colour of L* was , a* and b* value of modified millet flour ranged between 111.94 ± 2.02 and 137.40 ± 1.98, -3.66 ± 0.07 and -7.66 ± 0.07.

Table 1: Functional characteristics of native and modified millet flours.

<table>
<thead>
<tr>
<th>Millets</th>
<th>Water absorption index (g/100 g)</th>
<th>Water solubility index (g/100 g)</th>
<th>Water absorption capacity (ml/100g)</th>
<th>Oil absorption capacity (ml/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Native flour</td>
<td>Modified flour</td>
<td>Native flour</td>
<td>Modified flour</td>
</tr>
<tr>
<td>Kodo millet</td>
<td>8.27 ± 0.31</td>
<td>5.39 ± 0.18</td>
<td>9.08 ± 0.28</td>
<td>4.04 ± 0.15</td>
</tr>
<tr>
<td>Little millet</td>
<td>8.72 ± 0.15</td>
<td>5.69 ± 0.13</td>
<td>6.68 ± 0.21</td>
<td>1.32 ± 0.02</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>8.25 ± 0.30</td>
<td>5.24 ± 0.22</td>
<td>9.62 ± 0.35</td>
<td>2.76 ± 0.01</td>
</tr>
<tr>
<td>Proso millet</td>
<td>7.40 ± 0.32</td>
<td>5.26 ± 0.11</td>
<td>6.16 ± 0.13</td>
<td>1.72 ± 0.06</td>
</tr>
</tbody>
</table>

All data are the Mean ± SD of three replicates.

Table 2: Colour value of native and modified millet flours.

<table>
<thead>
<tr>
<th>Millets</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kodo millet</td>
<td>117.75 ± 3.03</td>
<td>-6.25 ± 0.05</td>
<td>12.40 ± 0.47</td>
</tr>
<tr>
<td>Modified</td>
<td>133.21 ± 2.43</td>
<td>-6.55 ± 0.06</td>
<td>17.50 ± 0.42</td>
</tr>
<tr>
<td>Little millet</td>
<td>121.23 ± 2.79</td>
<td>-6.29 ± 0.04</td>
<td>11.13 ± 0.48</td>
</tr>
<tr>
<td>Modified</td>
<td>130.87 ± 4.24</td>
<td>-6.52 ± 0.21</td>
<td>16.96 ± 0.47</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>103.94 ± 4.40</td>
<td>-3.26 ± 0.04</td>
<td>37.97 ± 1.54</td>
</tr>
<tr>
<td>Modified</td>
<td>111.94 ± 2.02</td>
<td>-3.66 ± 0.07</td>
<td>47.02 ± 1.06</td>
</tr>
<tr>
<td>Proso millet</td>
<td>126.62 ± 1.70</td>
<td>-6.67 ± 0.07</td>
<td>31.10 ± 1.33</td>
</tr>
<tr>
<td>Modified</td>
<td>137.40 ± 1.98</td>
<td>-7.66 ± 0.07</td>
<td>32.22 ± 1.00</td>
</tr>
</tbody>
</table>

Results are Mean ± SD of three determinations.

Table 3: Phytochemical components of native and modified millet flours (mg/100g).

<table>
<thead>
<tr>
<th>Millet flours</th>
<th>Total polyphenols (mg/100g)</th>
<th>Antioxidant (mg AAEAA/100g)</th>
<th>Phytate (mg/100g)</th>
<th>Tannin (mg TAE/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Native flour</td>
<td>Modified flour</td>
<td>Native flour</td>
<td>Modified flour</td>
</tr>
<tr>
<td>Kodo millet</td>
<td>368.77±11.17</td>
<td>362.38±14.08</td>
<td>70.82±3.07</td>
<td>66.85±2.55</td>
</tr>
<tr>
<td>Little millet</td>
<td>373.67±12.16</td>
<td>369.84±11.33</td>
<td>67.63±1.22</td>
<td>63.92±1.21</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>333.63±13.23</td>
<td>328.68±13.36</td>
<td>83.27±2.28</td>
<td>80.73±2.41</td>
</tr>
<tr>
<td>Proso millet</td>
<td>361.87±10.54</td>
<td>357.85±14.52</td>
<td>65.74±2.07</td>
<td>61.85±1.84</td>
</tr>
</tbody>
</table>

Results are Mean ± SD of three determinations.
0.07 and 17.50 ± 0.42 and 47.02 ± 1.06, respectively. The colour value of hydrothermally processed millet was darker than native millet and decorticated millet (Shobana, 2009). Helen (2010) found that the time of fermentation increased the color of flour also increased, while vice versa during germination process. However, during cooking the color of germinated flour was darker than the other treatments (Kikafunda et al., 2006).

**Dietary fibre profile of native and modified millet flours**

The data pertaining to dietary fibre profile of native flour and modified millet flour are presented in fig. 1. The soluble, insoluble and total dietary fibre content was observed to be high in modified millet flour than native flour. Native flour, the soluble fibre content was observed to be high in little millet flour (4.78 ± 0.01) followed by kodo millet flour (4.57 ± 0.05), proso millet (4.12 ± 0.03), wheat flour (1.63 ± 0.02) and pearl millet flour (1.23 ± 0.02), insoluble fibre content ranged from 5.69 ± 0.23 to 12.20 ± 0.47 and total dietary fibre content ranged between 7.32 ± 0.33 and 14.06 ± 0.36 g/100g. Modified millet flour, the soluble fibre content was 5.89 ± 0.05, 5.40 ± 0.02, 5.31 ± 0.05 and 2.37 ± 0.05 g/100g in little millet flour, kodo millet flour, proso millet flour and pearl millet flour. The insoluble and total dietary fibre content ranged from 9.44 ± 0.36 to 12.81 ± 0.55 and 14.84 ± 0.41 to 16.28 ± 0.50 g/100g respectively. Millet contain appreciable amount of dietary fibre (9-16%) even after removal of husk and major portion of bran (Hadinani and Malleshi, 1993). Roopa et al. (2012) found that soluble dietary fibre content of little millet contained 3.01 to 3.25 g/100 g and total dietary fibre content was 8.25 to 8.60 g/100 g respectively. Florence and Asna (2011) found that the insoluble dietary fibre content of pearl millet ranged from 10.9 to 12.6 g/100g, soluble dietary fibre (0.70 to 1.05), total dietary fibre (11.9 to 13.3 g/100g).

**Phytochemical components of native and modified millet flours**

Phytochemical components of native and modified millet flours are given in table 3. Phytochemical components such as total polyphenols, antioxidant activity, phytate and tannin were observed to be high in native flour than modified millet flour by heat moisture treatment or autoclaving and cooling cycle method. There will be reduction in phytochemical components due to heat moisture treatment of millet and this may provide nutritional advantages with respect to increased bioavailability of minerals and protein. Modification of millets improved its nutritive value by decreasing the tannin content, improving in vitro protein digestibility and in vitro starch digestibility.

Among the native millet flours, little millet flour contained higher proportions of polyphenols (373.67 ± 12.16 mg GAE/100 g) than kodo, proso and pearl millet flour (368.77 ± 11.17, 361.87 ± 10.54 and 333.63 ± 13.23 mg GAE/100g). Similar study by Chethan and Malleshi (2007) revealed that finger millet brown varieties contained (120-230 mg/100g) higher proportions of polyphenols than white (30 - 50 mg/100g) varieties. The polyphenol content of the millet varieties ranged from 30 to 230 mg/100g. The tiny millet grain has a dark brown seed coat, richer in polyphenols compared to other
continental cereals such as barley, rice, maize and wheat (Viswanathan et al., 2009). Hotz and Gibson (2007) also stated that certain tannins and other polyphenols in legumes and sorghum may also be reduced during germination as a result of formation of polyphenols complexes with proteins and the gradual degradation of oligosaccharides. Such reductions in polyphenols may facilitate iron absorption. An inverse relationship between tannin content and in vitro protein digestibility has been reported for germinated finger millet (Mbithi et al., 2000). Elyas et al. (2002) stated that natural fermentation of pearl millet decrease polyphenols and phytic acid and causes no changes in tannin contents.

Antioxidant activity was high in pearl millet flour (83.27 ± 2.28 mg AAEAA/100g) followed by kodo millet, little millet and proso millet (70.82 ± 3.07, 67.63 ± 1.22 and 65.74 ± 2.07 mg AAEAA/100g, respectively). Similar study by Ismail et al. (2010) examined total antioxidant capacity of finger, little, foxtail and proso millets were found to be higher. The phytate content was maximum in kodo millet flour (35.17 ± 0.63 mg/100g) whereas pearl millet, proso millet and little millet contained 33.42 ± 0.52, 27.17 ± 0.47 and 24.42 ± 0.55 mg/100g, respectively. The tannin content was maximum in proso millet flour (22.67 ± 0.21 mg TAE/100g, respectively) followed by kodo millet, little millet and pearl millet (22.53 ± 0.24, 18.62 ± 0.15 and 13.45 ± 0.39 mg TAE/100g, respectively).

Conclusion

The functional properties and phytochemical components of native and modified millet flours were studied. Results obtained in this study indicated that the millets are a good source of soluble, insoluble and total fibre content. Phenolic compounds and antioxidant activity was high in almost all millets.

References


