# Cooking qualities of parboiled little millet and proso millet: effect of soaking and steaming

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**Abstract:** Parboiling of little millet (*Panicum sumatrense*) and proso millet (*Panicum miliaceum*) was carried out by soaking at different soaking temperatures (30°C, 40°C, 50°C, 60°C and 70°C) and durations of steaming (10min, 15 min, 20 min, 25 min and 30 min). The parboiled millet grains were shade dried and pearled in a laboratory scale pearler cum polisher. Parboiling of these millets was assessed for the cooking qualities, in terms of cooking time, water uptake, swelling index and elongation ratio. Parboiled little millet took 9min-14 min for cooking with water uptake ratio of 3.1-4.7 and showed swelling index and elongation ratio ranging from 1.73-2.78 and 1.53-2.61, respectively. For proso millet cooking time and water uptake were recorded as 11 min -13 min and 2-4.2, with swelling index and elongation ratio of 0.7-1.72 and 1.42-4.26, respectively. Soaking at 50°C and 60°C and steaming for 25 min and 10 min, respectively, for little millet and proso millet yielded higher cooking qualities, *viz*., water uptake, swelling index and elongation ratio, and with less cooking time, which are considered as optimum conditions.

**Keywords:** little millet, proso millet, parboiling, cooking qualities, cooking time, water uptake, swelling index, elongation index.

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## 1 Introduction

The name 'millet' is applied to a group of small seeded annual grasses belonging to family *Poaceae* which were the first crops to be cultivated prior to plough age. The origin of millet is diverse with varieties coming from both Asia and Africa. Millet is more resistant to drought and has a shorter growing cycle than other major cereal grains (Devi et al., 2014) and this make millet an ideal crop for assuring food security in semi-arid areas in Asia and Africa. Millets have been important foods and feed crops producing more reliable harvest than many other crops (Deshpande and Nishad 2021).There are around 6,000 varieties of millet throughout the world with grains varying in colour from pale yellow to grey, white, and red. Sorghum (*Sorghum bicolour*) and pearl millet (*Pennissetum glaucum*) are considered as the major millets and other millets *viz*., finger millet (*Eleusine coracana)*, foxtail millet (*Setaria italica),* kodo millet *(Paspalum scrobiculatum)*, little millet *(Panicum sumatrense)*, proso millet *(Panicum miliaceum)* and barnyard millet (*Echinochloa crusgalli*) as the small millets. Besides, millets are rich in phytochemicals and nutrients such as B vitamins, minerals (calcium and iron), phosphorus (mainly phytate), dietary fiber and polyphenols (Saleh et al., 2013; Zhu, 2014), endowing millets several potential health benefits. Considering the importance of the millets in India towards the food and nutritional security, Government of India has declared the millets as

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Ready to eat/cook products from various millets, in the form of novel foods, convenience mixes from pearl millet (Balasubramanian and Yadav et al., 2014; Balasubramanian and Kaur et al.,2014), pasta from pearl millet, nutrient rich noodles supplemented with malted finger millet flour (Kulkarni et al.,2012), expanded millet, a ready-to-eat new generation product from decorticated finger millet (Ushakumari et al., 2007), finger millet incorporated noodles for nutritive value and glycemic index (Shukla and Srivastava, 2014), finger millet and pearl millet flour based pasta replacing durum wheat semolina (Gull et al., 2015), semolina from foxtail millet (Dharmaraj et al., 2016), gelatinized foxtail millet (α millet) (Wang, 2017) were developed by the earlier researchers.

Millet is processed by dehulling to remove husk, the non-edible component of grain. Dehulled grains are polished / decorticated to remove bran and pearled grains cooked into discrete grains similar to rice or further subjected to size reduction and the flour can be used in many traditional as well as contemporary products (Ushakumari et al.,2004). Hydrothermal treatment to the millet hardens the endosperm texture and enables its decortication for food uses rather than flour based products (Shobana and Malleshi, 2007). Hydrothermal processing also enhances the carbohydrate and protein digestibility of finger millet. Decortication even though lowered the overall nutrients, will increase the bioavailability of the nutrients including the calcium due to decreased dietary fiber, polyphenol and phytic acid contents. Thus, hydrothermal treatment and decortication of finger millet may enhance its product diversification opportunities.

Parboiling, a three-step hydrothermal treatment consisting of soaking, heating and drying of rough rice or any food grain, substantially reduces the level of broken kernels. It increases head rice yield (Messia et al., 2012; Buggenhout et al., 2013) increase its textural, nutritional value and resistance to spoilage by insects and mould (Messia et al., 2012; Buggenhout et al., 2014; Purohit and Srinivas, 2017). Though initially the hydrothermal treatment, parboiling was developed and adopted for paddy, considering the various requirements, the process has been adopted for finger millet (Dharmaraj and Malleshi, 2011) and foxtail millet (Dharmaraj et al., 2016) to increase its use and product diversification.

Francis and Emeka (2020) parboiled African breadfruit seed as a pre-hulling treatment and reported that the physical properties, *viz*., dimensions, sphericity, aspect ratio, bulk density, true density, thousand seed mass and surface area increased with parboiling duration (0 to 10 min.) and the angle of repose had no definite trend. These studies, especially on millets are limited only to the level of giving a pre-treatment with aim of product diversification. The process of parboiling and the associated quality parameters are yet to be studied for further adoption and towards utility for the millets. Among the minor millets, little millet and proso millet are much underutilized compared to finger millet and foxtail millet. In view of the situation presented, this study was conducted to assess the feasibility of parboiling of these selected minor millets and evaluate the cooking qualities.

## 2 Materials and methods

### 2.1 Raw materials

The bulk grains of little millet (*Panicum sumatrense*) and proso millet (*Panicum miliaceum*) obtained from Department of Millets, Tamil Nadu Agricultural University, Coimbatore, India, were dried, cleaned and stored in air tight containers for use in experiments.

### 2.2 Moisture determination

All the moisture content estimation of grains was determined for the triplicate samples by measuring the loss in weight of 5 g sample by drying at 130ºC ± 2ºC for 2 h (AACC, 2000) in a ventilated hot air oven. All the weights were measured using an electronic balance with the least count of 0.001 g.

### 2.3 Laboratory model parboiling unit

A laboratory model of parboiling unit consisting of a drum with lid (250 mm inner diameter and 300 mm height), steam distributor and an electrical heating coil, was used for parboiling the millets. The steam distributor is fitted into the drum on an inclined support provided at 100 mm depth from the bottom, acts as vapour space. The steam distributor is provided with vertical main pipe (20 mm diameter for 150 mm height) and lateral pipes (15 mm diameter and 120 mm length) for uniform distribution of vapour / steam. Below the steam distributor unit, an immersion heater of 1000 W (kettle type) capacity is provided. The bottom portion of the drum is filled with water to completely immerse the heater and the heater is switched on. When water started boiling, as heated by the immersion heater, steam produced is distributed uniformly through the central vertical pipe and laterals, to the grain mass already soaked and placed for parboiling. As the end of parboiling, as noted from either splitting or the characteristic smell, the parboiled grains were removed through the outlet or opening the lid. Dharmaraj and Malleshi (2011) steamed soaked finger millet in an autoclave spread in steel trays (80cm×40cm×3 cm) for 25 mm bed thickness at atmospheric pressure with suitable power connection.

### 2.4 Soaking the millet grains

The food grains are soaked either in cold or hot water for parboiling and soaking in hot water reduces the duration for reaching saturation. Based on the soaking temperature of 25°C-70°C for 1-4 h followed by the earlier researchers for paddy (Venkatachalapathy and Udhayakumar, 2013; Nasirahmadi et al., 2014; Buggenhout et al., 2014) and for finger millet (Shobana and Malleshi,2007; Dharmaraj and Malleshi, 2011; Dharmaraj et al., 2016) and foxtail millet (Wang, 2017),soaking of little millet and proso millet grains were done at temperatures of 30°C, 40°C, 50°C, 60°C and 70°C for the duration as given in Table 1 to reach equilibrium (Balkrishna and Visvanathan, 2019). In the remaining of the text when mentioned soaking at a particular temperature will mean soaking for the corresponding time to reach equilibrium as given in Table 1. Sample of about 250 g filled in cloth bag was soaked in a thermostatically controlled water bath at these temperatures and the corresponding soaking durations.

### 2.5 Parboiling of the millet grains

Steaming of little and proso millet grains at atmospheric pressure was done for various durations of 10, 15, 20, 25 and 30 min time, based on the durations, 1 to 40 min followed for paddy (Venkatachalapathy and Udhayakumar, 2013; Purohit and Rao, 2017; Buggenhout et al., 2014; Nasirahmadi et al., 2014), finger millet (Shobana and Malleshi,2007; Wang, 2017) and foxtail millet (Dharmaraj et al., 2016).The steaming duration was reckoned from the generation of steam. To facilitate conducting the steaming studies for these durations, 5 samples of soaked grains in cloth bags were placed simultaneously in the vapour space of the parboiling tank. The samples after steaming were taken out for shade drying.

**Table 1 Soaking duration required for the experimental samples to reach equilibrium moisture content at indicated temperatures of soaking**

| Millet grain | Soaking temperature (°C) | Initial moisture content (% d.b) | Equilibrium moisture content (% d.b) | Soaking duration (h) |
|---|---|---|---|---|
| Little millet | 30 | 11.02 | 38.00 | 18.5 |
| | 40 | 11.02 | 39.70 | 17 |
| | 50 | 11.02 | 49.27 | 15 |
| | 60 | 11.02 | 50.17 | 8 |
| | 70 | 11.02 | 49.80 | 3.5 |
| Proso millet | 30 | 10.45 | 39.11 | 19 |
| | 40 | 10.45 | 41.72 | 17 |
| | 50 | 10.45 | 43.72 | 15 |
| | 60 | 10.45 | 44.19 | 8 |
| | 70 | 10.45 | 47.15 | 4 |

### 2.6 Drying

Drying is the third major unit operation in the parboiling process. Shade drying was adopted (30°C±2°C; 65%-70% relative humidity) for drying the parboiled samples. The experimental samples after parboiling were spread in galvanised iron trays in a single layer and shade dried sufficiently to the moisture content of 12-14% (w.b.).Well dried parboiled samples were packaged separately as per the treatments in 200 micron thick polypropylene bags and kept safely in air tight containers for the further analysis.

### 2.7 Pearling

Abrasion type table top rice polisher was used for dehusking and polishing together for the parboiled little and proso millet grains. This unit, operated by a one hp motor, is made of abrasion disc (rotating vertically), normally used for polishing of rice grains at laboratory level. Similar polishing unit was used by Shobana and Malleshi (2007) and Dharmaraj et al. (2016). Polishing was done by taking about 150 g of sample and the degree of polishing was limited to 6%, moderate polish (Dharmaraj et al., 2016). It took about 10 min-12 min to complete polishing to this desired level. Care was taken during polishing to avoid breakage of grains by adjusting the clearance between the abrasion disc and the concave.

### 2.8 Cooking qualities of parboiled samples

Cooking qualities of the parboiled millet samples were assessed through the determination of cooking time, water uptake ratio, swelling index and elongation ratio.

2.8.1 Cooking time

Cooking time is the highly significant aspect of cooking quality. The optimal cooking time for the grains and other products like pasta are generally determined following the Ranghino test (Juliano and Bechtel, 1985). By this method, the cooked white core in the grain / pasta is still present but disappeared after squeezing between two clean glass slides / plates and observed under polarized light. Cooking time is recorded when at least 90% of the grains no longer had an opaque core or an uncooked centre. Since till day no exclusive methodology was developed for the assessment of cooking time for millets, Ranghino test was followed in this study.

Twenty numbers of test tubes of 23 mm diameter and 150 mm length, filled with 5 g of pearled millet grains and 25mL of distilled water placed in a water bath under heating, when the water temperature reached 98ºC. The initial water level in the test tube was noted to measure the water uptake during cooking. After every one minute, one test tube was taken out and immediately immersed in cold water to stop further cooking. Simultaneously, two grains were taken out randomly from every removed test tube and pressed between two glass slides. Disappearance of white core in the grain after squeezing and softness at pressing is judged as cooked and the corresponding exposure time is the optimum cooking time. Cooking time was determined for both parboiled as well as raw millet grain samples. Mohapatra and Bal (2006), Gull et al. (2015) and Ziegler et al. (2018) also followed similar method for rice samples.

2.8.2 Water uptake ratio

Water uptake is the ratio of water absorbed by the grains during cooking to the initial weight of uncooked rice. More the amount of water absorbed cooking will be better. Water uptake was determined from the data recorded from the cooking experiments to determine the cooking time.

The millet grains placed in the test tubes for cooking experiment for various durations of cooking, the test tube with grains judged for the optimum cooking was taken for the determination of water uptake ratio. With the initial and final water levels marked in the test tube, corresponding volume of water uptake was determined using the water replacement method. Mohapatra and Bal (2006) and Gayin et al. (2017) used this method for rice. Since no established and exclusive methodology is standardised for millet grains, this method popularly followed for rice kernels was used. From the volume of water absorbed during cooking, water uptake ratio was calculated as follows:

$$W_{up} = \frac{(v_{bc} - v_{ac})\rho_w}{w_g} \tag{1}$$

Where, $W_{up}$- water uptake ratio, $v_{bc}$-volume of water in the test tube, before cooking, mL, $v_{ac}$ - volume of water in the test tube, after cooking, mL, $\rho_w$- density of water, gmL$^{-1}$, and $w_g$ - mass of grains before cooking, g.

2.8.3 Swelling index

Swelling index is also the volume expansion ratio, the ratio of the final volume of the cooked grains to the initial volume of the grains. It was determined for grains in bulk of grains rather than for a single grain. Swelling index was determined simultaneously with the cooking time.

With the initial and final grain levels marked in the test tube, corresponding volume of grain was determined using water replacement method. Mohapatra and Bal (2006) also suggested the same method for rice. Using the readings recorded, swelling index was calculated as follows using the following formula,

$$I_s = \frac{V_f - V_i}{V_i} \tag{2}$$

Where, $I_s$-swelling index, $V_f$- volume of grains after cooking, cm$^3$, and $V_i$- volume of grains before cooking, cm$^3$.

2.8.4 Elongation ratio of grains

Elongation ratio is the ratio between the dimensions of cooked and uncooked grain. Mohapatra and Bal (2006) and Gayin et al. (2017) determined the length expansion ratio for rice as the ratio of the length of cooked grain to length of uncooked grain. In case of millets, spherical in shape, the appropriate dimensions are diameter along major axis and minor axis. About 10 grains were randomly selected from the unsoaked grains used for parboiling and the parboiled sample, and their major and minor axes were measured using a screw gauge with 0.1 mm least count. Elongation ratio was calculated for both raw and parboiled millet grains using the following formula (Giri and Bandyopadhyay, 2000):

$$E_r = \frac{M_{jf}}{M_{ji}} \times \frac{M_{nf}}{M_{ni}} \tag{3}$$

Where, $E_r$-elongation ratio, $M_{ji}$-axis before cooking, mm, $M_{jf}$-major axis after cooking, mm, $M_{ni}$-minor axis before cooking, mm, and $M_{nf}$- minor axis after cooking, mm.

**2.8 Statistical analysis**

All the experiments were replicated three times and the data statistically analysed using MS Excel and AgRes ANOVA softwares. The mean values are reported.

## 3 Results and discussion

**3.1 Cooking time**

The analysis of variance of cooking time of parboiled little millet shows the effect of soaking temperature and steaming duration as significant at 1% level (Tables 2 and 3). Among the various combinations of soaking temperature and steaming duration, 30°C (10min, 15 min and 20 min), 40°C (10 min, 15 min and 20 min) and, 60°C and 70°C (10 min) have shown the lowest cooking time of 9 min, which is at par. The control sample of little millet was cooked at 7 min indicating the minimum time taken for cooking. Higher cooking time of 14 min was observed for the samples cooked with 30 min duration after soaking at 50°C. The samples soaked at higher temperatures and cooked with longer durations resulted in higher cooking time as in the case of other grains.

For the parboiled proso millet grains, the cooking time determined with respect to the soaking temperature and steaming duration treatments are statistically significant at 1% level (Table 4).The lowest cooking time of 11 min was noted (Table 5) at the soaking temperature and steaming duration of 30°C (15 min), 40°C (10 min), 50°C and 60°C (10 min, 20 min, 25 min and 30 min), and 70°C (10 and 25 min), which are at par. With the control sample (raw proso millet grain) exhibited 10 min of cooking time, all the other treatment combinations which were at par has shown 12 min of cooking time, except 40°C

(30 min) which has shown 13 min of cooking time. Proso millet has tight and hard layers which takes longer cooking duration, irrespective of hydrothermal treatment.

Cooking time of 17-21 min (Gayin et al., 2017), 22-16 min (Mohapatra and Bal, 2006), 23-33 min (Ziegler et al., 2018), for rice under various treatments and 3-5 min (Dissanayaru and Jayawardena, 2016) for finger millet- rice noodles were noted in the literature.

**Table 2 Analysis of variance (ANOVA) for cooking properties of parboiled little millet grains**

| Source of variation | Degrees of freedom | Sum of squares | Mean squares | F-ratio |
|---|---|---|---|---|
| Cooking time | | | | |
| Treatment | 24 | 2.442 | 0.102 | 1343.12** |
| Soaking temperature (t) | 4 | 1.2464 | 0.312 | 4113.12** |
| Steaming duration (T) | 4 | 0.926 | 0.232 | 3057.73** |
| t × T | 16 | 0.269 | 0.017 | 2219.74** |
| Error | 50 | 0 | 0 | 1 |
| Total | 74 | 2.442 | 0.033 | 4356.08 |
| Water uptake | | | | |
| Treatment | 24 | 9.239 | 0.385 | 144.36** |
| Soaking temperature (t) | 4 | 3.824 | 0.956 | 358.57** |
| Steaming duration (T) | 4 | 2.136 | 0.534 | 200.32** |
| t × T | 16 | 3.277 | 0.205 | 76.82** |
| Error | 50 | 0.133 | 0.003 | 1 |
| Total | 74 | 9.372 | 0.126 | 47.49 |
| Swelling index | | | | |
| Treatment | 24 | 2.442 | 0.102 | 1343.12** |
| Soaking temperature (t) | 4 | 1.246 | 0.311 | 4113.12** |
| Steaming duration (T) | 4 | 0.926 | 0.231 | 3057.73** |
| t × T | 16 | 0.269 | 0.016 | 2219.74** |
| Error | 50 | 0 | 0 | 1 |
| Total | 74 | 2.442 | 0.033 | 4356.08 |
| Elongation ratio@ | | | | |
| Treatment | 24 | 17.980 | 0.749 | 6.07** |
| Steaming duration (t) | 4 | 2.718 | 0.679 | 5.51** |
| Steaming duration (T) | 4 | 3.548 | 0.887 | 7.19** |
| t × T | 16 | 11.713 | 0.732 | 5.93** |
| Error | 225 | 27.751 | 0.123 | 1 |
| Total | 249 | 45.732 | 0.183 | 1.48 |

Note: @with 10 replications; * significant at 5% level; ** significant at 1% level.

### 3.2 Water uptake

The effect of soaking temperature (t) and steaming duration (T) on water uptake ratio of parboiled little millet (Table 2) was significant at 1% level. The soaking temperature and steaming duration combination of 50°C and 30 min resulted in the maximum water uptake ratio of 4.7 $gg^{-1}$, followed by the combination 50°C (25 min) and 60°C (15 min) with water uptake ratio of 4.5 and 4.3$gg^{-1}$, respectively (Table 3). With the control sample shown to have a water uptake ratio of 3.7 $gg^{-1}$, the minimum water uptake of 3.1 $gg^{-1}$was found at the combination of 60°C and 10 min.

Statistical analysis of water uptake ratio of parboiled proso millet as given in Table 4 has shown significant effect at 1% level on soaking temperature and steaming duration. Among the different combinations of soaking temperature and steaming duration, the combination of 40°C (10 min) and 60°C (10 min) has exhibited the maximum water uptake ratio of 3.8 and 4.2 $gg^{-1}$, respectively which are at par (Table 5). These values are followed by 3.1 to 3.8 $gg^{-1}$ as water uptake ratio for the process parameters levels of 30°C (10 and 15 min), 60°C (10 min) and 70°C (10min, 15min and 20 min), which are at par. The raw proso millet grain (control) has shown a water uptake ratio of 3.3 and the minimum value of 2 $gg^{-1}$ was obtained in the combination of 40°C (20 min).

Increase in water uptake may be due to the soaking at higher temperatures and longer duration of steaming, which softened the grains. The reason for the decrease in water uptake at lower soaking temperatures and increase in steaming duration is not understood, however may be the grains become harder.

**Table 3 Cooking qualities of parboiled little millet grains***

| Soaking temperature for parboiling (ºC) | Steaming duration (min) | Cooking time (min) | Water uptake ($gg^{-1}$) | Swelling index | Elongation ratio |
|---|---|---|---|---|---|
| 30 ($t_1$) | 10 ($T_1$) | $9^a$ | 3.7 | 1.73 | $2.35^{abc}$ |
| | 15 ($T_2$) | $9^a$ | 3.7 | 1.80 | $2.31^{abc}$ |
| | 20 ($T_3$) | $9^a$ | 3.9 | 1.80 | 1.69 |
| | 25 ($T_4$) | $10^b$ | 4.0 | 1.75 | $2.07^c$ |
| | 30 ($T_5$) | $10^b$ | 4.1 | 1.80 | $2.07^c$ |
| 40 ($t_2$) | 10 ($T_1$) | $9^a$ | 4.2 | 1.75 | $2.61^a$ |
| | 15 ($T_2$) | $9^a$ | 3.9 | 1.80 | $2.59^a$ |
| | 20 ($T_3$) | $9^a$ | 4.1 | 1.80 | $2.48^{ab}$ |
| | 25 ($T_4$) | $10^b$ | 4.2 | 1.86 | 1.88 |
| | 30 ($T_5$) | $11^c$ | 4.1 | 1.88 | 1.53 |
| 50 ($t_3$) | 10 ($T_1$) | $11^c$ | 4.0 | 2.16 | 1.77 |
| | 15 ($T_2$) | $11^c$ | 4.0 | 2.27 | $2.21^{bc}$ |
| | 20 ($T_3$) | $11^c$ | 4.1 | $2.39^c$ | 1.82 |
| | 25 ($T_4$) | 12 | $4.5^b$ | $2.57^b$ | $2.22^{bc}$ |
| | 30 ($T_5$) | 14 | $4.7^a$ | $2.78^a$ | $2.27^{bc}$ |
| 60 ($t_4$) | 10 ($T_1$) | $9^a$ | 3.1 | 2.16 | $2.30^{abc}$ |
| | 15 ($T_2$) | $10^b$ | $4.3^c$ | 2.12 | $2.30^{abc}$ |
| | 20 ($T_3$) | $11^c$ | 3.9 | 1.90 | $2.15^c$ |
| | 25 ($T_4$) | $11^c$ | 3.8 | 1.88 | $2.25^{bc}$ |
| | 30 ($T_5$) | $11^c$ | 4.2 | 2.00 | $2.21^{bc}$ |
| 70 ($t_5$) | 10 ($T_1$) | $9^a$ | 3.5 | 2.22 | $2.08^c$ |
| | 15 ($T_2$) | $10^b$ | $3.3^c$ | $2.31^c$ | 1.99 |
| | 20 ($T_3$) | $10^b$ | 3.5 | $2.55^b$ | 1.90 |
| | 25 ($T_4$) | $11^c$ | 3.7 | $2.72^a$ | 2.03 |
| | 30 ($T_5$) | $11^c$ | 3.9 | $2.74^a$ | 1.80 |
| Control | Raw grain | 7 | 3.7 | 1.23 | 1.37 |

Note: *All the treatments bearing same alphabet belong to one group and are on par.

### 3.3 Swelling index

Swelling index is the volumetric expansion cooked grains and the higher values are desirable. For the parboiled grains the parameters of hydrothermal treatments influence this cooking quality. As given in Table 2, the analysis of the variance of the data has shown significant effect of soaking temperature and steaming duration on swelling index at 1% level for the little millet. The maximum swelling index of 2.72 to 2.78 (Table 3) was exhibited by the combinations of soaking temperature and steaming duration, 70ºC (25 min and 30 min) and 50ºC (30 min), which were at par. This swelling index was followed by 2.55 and 2.57 at the combinations of 70ºC (20 min) and 50 ºC (25 min), respectively. The swelling index for the control (raw little millet grain) was 1.23 and the minimum value noted was 1.73 at the combination of 30ºC and 10 min. Higher temperatures of soaking and steaming duration resulted in higher swelling than the lower soaking temperature and steaming duration.

As seen from Table 4, the swelling index for proso millet was significant at 1% level with the soaking temperature (t) and steaming duration (T). From the different combinations of soaking temperature and steaming duration as process parameters to assess the cooking qualities, the combinations, 30ºC (10 min and 15 min) and 40ºC (10 min), have shown the maximum swelling index of 1.69 to 1.72, which is at par (Table 5). These values are followed by 1.35 to 1.45, for the soaking temperature and steaming duration combination of 60ºC (10 min) and 70ºC (10 min, 15 min and 30 min), which were found to be at par. The minimum value of swelling index of 0.7 was observed at 40ºC (20 min) and for the control sample it was found to be 1.19.

**Table 4 Analysis of variance (ANOVA) for cooking properties of parboiled proso millet grains**

| Source of variation | Degrees of freedom | Sum of squares | Mean squares | F-ratio |
|---|---|---|---|---|
| Cooking time | | | | |
| Treatment | 24 | 0.514 | 0.021 | 1488.88** |
| Soaking temperature (t) | 4 | 0.181 | 0.045 | 3134.66** |
| Steaming duration (T) | 4 | 0.077 | 0.019 | 1340.95** |
| t × T | 16 | 0.257 | 0.016 | 1114.42** |
| Error | 50 | 0 | 0 | 1 |
| Total | 74 | 0.514 | 0.007 | 4828.82 |
| Water uptake | | | | |
| Treatment | 24 | 12.159 | 0.868 | 6.56** |
| Soaking temperature (t) | 4 | 7.017 | 1.754 | 13.26** |
| Steaming duration (T) | 4 | 0.526 | 0.263 | 1.98** |
| t × T | 16 | 4.616 | 0.577 | 4.36** |
| Error | 50 | 3.967 | 0.132 | 1 |
| Total | 74 | 16.126 | 0.366 | 2.77 |
| Swelling index | | | | |
| Treatment | 24 | 5.682 | 0.236 | 81.89** |
| Soaking temperature (t) | 4 | 1.498 | 0.374 | 129.53** |
| Steaming duration (T) | 4 | 2.832 | 0.708 | 244.93** |
| t × T | 16 | 1.352 | 0.085 | 29.22** |
| Error | 50 | 0.145 | 0.003 | 1 |
| Total | 74 | 5.826 | 0.079 | 27.23 |
| Elongation ratio@ | | | | |
| Treatment | 24 | 112.686 | 4.695268 | 155.42** |
| Soaking temperature (t) | 4 | 80.794 | 20.1987 | 668.60** |
| Steaming duration (T) | 4 | 11.386 | 2.846705 | 94.23** |
| t x T | 16 | 20.505 | 1.281549 | 42.42** |
| Error | 225 | 6.797 | 0.03021 | 1 |
| Total | 249 | 119.483 | 0.479854 | 15.88 |

Note: @with 10 replications; * significant at 5% level;** significant at 1% level.

### 3.4 Elongation ratio

Besides the volumetric expansion of cooked grains, linear dimensions also expand and assessed in terms of elongation ratio. From the statistical analysis of the data (Table 2and 3) of elongation ratio of parboiled little millet, it is clear that the effect of soaking temperature (t) on water uptake ratio was significant at 1% level. The process parameter combinations of soaking temperature and steaming duration, 30ºC (10 min and 15 min), 40ºC (10 min, 15 min and 20 min) and 60ºC (10 min and 15 min) had shown the maximum elongation ratio of 2.30 to 2.61, which were at par. The minimum values of elongation ratio of 1.53 was observed at soaking temperature and steaming duration of 40ºC and 30 min and the elongation ratio for the control sample (raw grains of little millet) was 1.37.

The values of elongation ratio of parboiled proso millet grains with reference to the soaking temperature and steaming duration and the corresponding analysis of variance are given in Tables 4 and 5.It is observed from the analysis of variance, the effect of soaking temperature and steaming duration on elongation ratio is significant at 1% level. Among the different combinations of soaking temperature and steaming duration, 4.26 was the maximum value of elongation ratio observed at 70ºC (10 min) followed by 3.81 at the combination of 70ºC (15 min). The minimum value of 1.42 was noted at the combination of 50ºC (15 min) and the control value was 2.15. The elongation ratio increased with increase in soaking temperature. Lower values of elongation were noted at lower temperatures of soaking at all steaming durations. Partial elongation is achieved during soaking at elevated temperatures and thus further elongation during steaming. Elongation ratio of 1.41 to1.62 (Gayinet al., 2017) and 1.36 to 1.72 (Mohapatra and Bal, 2006) were reported for rice samples.

**Table 5 Cooking qualities of parboiled proso millet grains**

| Soaking temperature for parboiling (°C) | Steaming duration (min) | Cooking time (min) | Water uptake ($gg^{-1}$) | Swelling index | Elongation ratio |
|---|---|---|---|---|---|
| 30 ($t_1$) | 10 ($T_1$) | $12^b$ | $3.6^b$ | $1.72^a$ | 2.67 |
| | 15 ($T_2$) | $11^a$ | $3.5^{bc}$ | $1.69^a$ | 2.92 |
| | 20 ($T_3$) | $12^b$ | 2.8 | 1.22 | 2.88 |
| | 25 ($T_4$) | $12^b$ | 3.2 | $1.35^c$ | 2.06 |
| | 30 ($T_5$) | $12^b$ | 2.9 | 1.30 | 2.14 |
| 40 ($t_2$) | 10 ($T_1$) | $11^a$ | $4.2^{ac}$ | $1.69^a$ | 2.20 |
| | 15 ($T_2$) | $12^b$ | $2.6^c$ | 1.29 | 2.23 |
| | 20 ($T_3$) | $12^b$ | 2.0 | 0.70 | 1.88 |
| | 25 ($T_4$) | $12^b$ | 2.5 | 0.74 | 1.59 |
| | 30 ($T_5$) | $13^c$ | 3.0 | 1.22 | 1.47 |
| 50 ($t_3$) | 10 ($T_1$) | $11^a$ | 2.8 | $1.35^c$ | 2.07 |
| | 15 ($T_2$) | $12^b$ | 2.8 | 1.28 | 1.42 |
| | 20 ($T_3$) | $11^a$ | 2.9 | 1.07 | 1.69 |
| | 25 ($T_4$) | $11^a$ | 3.2 | 1.02 | 2.25 |
| | 30 ($T_5$) | $11^a$ | 3.9 | 1.28 | 2.19 |
| 60 ($t_4$) | 10 ($T_1$) | $11^a$ | $3.8^c$ | $1.45^b$ | 2.68 |
| | 15 ($T_2$) | $12^b$ | 3.3 | 1.10 | 2.67 |
| | 20 ($T_3$) | $11^a$ | 2.9 | 1.01 | 2.71 |
| | 25 ($T_4$) | $11^a$ | 2.5 | 0.88 | 2.40 |
| | 30 ($T_5$) | $11^a$ | 2.3 | 0.74 | 2.08 |
| 70 ($t_5$) | 10 ($T_1$) | $11^a$ | $3.5^c$ | $1.37^{bc}$ | $4.26^a$ |
| | 15 ($T_2$) | $12^b$ | $3.4^{bc}$ | $1.37^{bc}$ | $3.81^b$ |
| | 20 ($T_3$) | $12^b$ | $3.1^{bc}$ | 1.12 | $3.03^c$ |
| | 25 ($T_4$) | 11 | 2.9 | 1.03 | $3.08^c$ |
| | 30 ($T_5$) | $12^b$ | 3.4 | $1.43^{bc}$ | $3.07^c$ |
| Control | Raw grain | 10 | 3.3 | 1.19 | 2.15 |

Note: *All the treatments bearing same alphabet belong to one group and are on par.

## 4 Conclusions

Feasibility of parboiling of little millet (*Panicum sumatrense*), proso millet (*Panicum miliaceum*) by open steaming is seen through this study. Quality of parboiling with respect to soaking temperature and steaming duration was assessed based on cooking time, water uptake, swelling index and expansion ratio. The cooking qualities *viz*., cooking time, water uptake, swelling index and expansion ratio, were 9-14 and 11-13 min, 3.1-4.7 and 2-4.2 $gg^{-1}$,1.73-2.78 and 0.7-1.72, and1.53-2.61 and 1.42-4.26, for little millet and proso millet, respectively. Soaking at 50 and 60°C and steaming for 25 min and 10 min, respectively for little millet and proso millet yielded higher cooking qualities, viz., water uptake, swelling index and elongation ratio, and with less cooking time, which are considered as optimum conditions.

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