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Controlled germination for cooking quality and nutritional enhancement of underutilised little millets

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Little millet (*Panicum sumatrense*) is one of the underutilised indigenous nutricereals due to coarse nature and drudgery associated with processing. Minimal processing such as germination could convert it into edible form. The present study revealed that 24 h germinated little millets were better source of vitamin C (5.11 mg/100 g) and total soluble solids (2.33%) with substantial α-amylase activity (1.34 µg/100 g), milling yield (71.03%) and overall acceptability (8.73) for cooked grains compared to non-germinated and germinated ones for 12, 18, 36, 42 and 48 h. Germination enhanced hydration, swelling capacities by 25.71, 36.17% respectively and decreased bulk density, tapped density of little millets by 5.06, 5.88% respectively due to breakdown of complex components into simpler ones by hydrolytic enzymes. Consequently, germination enhanced water uptake ratio, elongation ratio, volume expansion ratio of cooked little millets by 19.35, 5.60, 39.51% respectively and decreased cooking time, gelatinisation temperature, solid content by 31.95, 20.26, 20.03% respectively. Further, it improved protein, fiber, total mineral contents by 6.92, 26.90, 130.77%, respectively and reduced moisture, fat, energy, reducing sugar contents by 5.79, 65.80, 5.74, 6.07% respectively due to activation of metabolic machineries which promoted synthesis and release of bound constituents by reducing antinutrients. These germinated little millets with better cooking quality, nutritional and sensory profile can be consumed by obese and diabetic people or utilised as functional ingredients for formulation of low bulk weaning and complementary mixes or nourishing convenience foods.

Keywords: Cooking quality, Germination, Little millet, Nutricereal, Physical parameters

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In the present-day scenario, food security and triple burden of malnutrition are the key issues to be addressed globally, amidst the day-to-day burgeoning population and challenges created by COVID-19 pandemic. With a score of 30.3, India suffers from a serious level of hunger and was ranked 102 out of 117 nations with extreme muscle wasting rate of 20.8% than any other countries[1]. Minor millets are the foremost cultivated ancient coarse cereals in India and provide millions of households with highly nutritious food and livelihood security, especially small and marginal farmers of remote tribal areas. Being subsistence crops, they possess unique ability to grow under harsh environmental conditions where major cereals such as wheat, rice and maize cannot be cultivated[2].

Indian tribal groups have a special link to minor millets as these crops have been an integral component of their agricultural systems and operations. They are also considered as 'famine reserves' as they could be stored up to two years or more[3]. Finger millet, barnyard millet, foxtail millet, proso millet, little millet, kodo millet and brown top millet are the seven cultivated species that represent minor millets. They are now no longer referred as coarse cereals but are being considered 'nutricereals' or 'nutraceutical crops' and could be a plausible answer for combating malnutrition and hidden hunger worldwide[4]. With the aim to generate awareness and increase production and consumption of indigenous millets, the United Nations at the behest of Government of India declared 2023 as the international year of millets.

Little millet (*Panicum sumatrense*) was domesticated in India more than 5000 years ago and is known as Indian millet[5]. It is commonly referred as 'sama' and is widely cultivated by rural farming communities in south and central India predominantly in hilly slopes with poor soil fertility[6]. Being a short duration crop of 65-75 days, it grows under diverse

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agroecological conditions and produce good grain yield with limited water supply in marginal lands[7]. Despite their agroeconomic and nutritional potential minor millets fall under the umbrella of 'underutilized', 'forgotten' or 'orphan' crops due to their coarse nature concomitant with poor research and novel techniques for their valorisation as food products[8].

Processing converts inedible grains to edible form, thereby enhancing their sensorial and nutritional quality. The practice of sprouting is widely used to improve the nutritional, biochemical and sensory characteristics of many grains. Germination activates metabolic machinery of seed and promotes release of many bioactive components by reducing antinutrients. However, the duration of this process is significant as extended germination reduces the activity of hydrolytic enzymes thereby reducing the conversion of complex grain components[9]. Henceforth, the present study was carried out to standardize the duration for optimum sprouting of little millets at constant soaking time and temperature and to compare the physical, cooking and nutritional characteristics of germinated little millets with non-germinated ones.

Materials and Methods

Sample preparation

The little millets analysed in the present study were pooled grains procured from the farmers of Telangana State and supplied by Indian Institute of Millets Research, Hyderabad. The grains were minute sized, slender, elliptical shaped and green in colour. The procured sample was freed from brokens, inert matter and other variety seeds to obtain pure seeds and was stored in airtight containers at room temperature till further investigation. The study was carried out in the Post Graduate & Research Centre and Central Instrumentation Cell, PJTSAU, Rajendranagar, Hyderabad. All the chemicals used were of analytical reagent grade.

Profiling of sprouting parameters of little millets

The raw little millets were soaked for 12 h at room temperature and incubated at 30°C for 12, 18, 24, 36, 42 and 48 h respectively. The sprouting parameters profiled for the determination of ideal duration of germination included germination capacity[10], radicle and shoot length, vitamin C content, titratable acidity, pH, total soluble solids (TSS) content, α-amylase activity[11], milling yield[12] and organoleptic acceptability of cooked millets at different incubation times. Germination capacity was the proportion of total germinated seeds and expressed as percentage. Non-germinated seeds represented dry seeds that were not in contact with water. The seeds in which cotyledons emerged before the radicle were considered as abnormally germinated.

Sensory parameters of cooked germinated little millets

For determining organoleptic acceptability, the germinated and dehulled little millets were cooked by adding 100 mL water to 25 g of sample. A 15-member trained panel from PGRC, PJTSAU evaluated the germinated little millets at different time intervals in a sensory evaluation lab using 9-point hedonic scale for colour, texture, flavour, taste and overall acceptability after cooking. The scores were based on a hedonic rating of 1 to 9 where: 1 indicated disliked extremely (very bad) and 9 was liked extremely (excellent)[13].

Physical properties of germinated little millets

The physical properties analysed for non-germinated and germinated little millets included colour, microscopic dimensions, thousand grain weight and volume, bulk and tapped densities, hydration and swelling capacity[12,14].

Cooking quality of germinated little millets

The cooking quality of non-germinated and germinated little millets was determined using water uptake ratio, elongation ratio, volume expansion ratio, cooking time, gruel solid loss, equivalent weight, solid content, gelatinization temperature, alkali degradation and microscopic structure of starches[12,15,16].

Nutritional characteristics of germinated little millets

The nutritional parameters analysed included moisture, ash, protein, fat, crude fiber, carbohydrate, energy, total, reducing and non-reducing sugar content[11] of non-germinated and germinated little millets.

Statistical analysis

The results obtained were statistically analysed to test the significance using percentages, means, standard deviations and Pearson's correlation coefficient[17]. The values obtained were presented as mean ± standard deviation of three parallel measurements.

Results and Discussion

Germination capacity of little millets

Germination began with the imbibition of water by seeds and ended with the emergence of radicle (Plate 1). The plotting of percentage of germinated seeds at each time interval resulted in sigmoid curve depicting speed and uniformity of germination (Fig. 1). The curve was skewed for longer germination times indicating the time required for first half of seed population to complete germination is shorter than the second half may be due to availability of complexes for breakdown initially. The germination percentage increased rapidly upto 36 h and thereafter remained more or less constant. The maximum germinated percentage was 97.33% with a mean score of 78.67% for 12-48 h of germination.

The abnormally germinated little millets percentage was highest at 24 h with 1.33% and mean score of 0.89% for 12-48 h of germination. The non-germinated percentage was highest at 12 h with 100% and mean score of 20.94%. There was statistically no significant difference at 5% level for germinated percentage at 36, 42 and 48 h, non-germinated percentage at 24, 36, 42 and 48 h whereas significant difference for abnormally germinated percentage at 18 and 24 h was observed. Similarly, other researchers[18] reported that the germination capacity of pearl millet increased significantly ($p \leq 0.05$) from 68.67% at 24 h to 88.83% at 60 h and remained constant thereafter.

Radicle and shoot length of germinated little millets

The radicle and shoot lengths were directly proportional to time duration as depicted in Figure 2. The length of radicle was longest at 48 h with 2.10 cm and mean score of 0.79 cm for 12-48 h of germination. Statistically significant difference between the radicle length of germinated little millets for different time intervals at 5% level. Likewise, the length of shoot was longest at 48 h with 1.30 cm and mean score of 0.42 cm for 12-48 h of germination. Statistically significant difference between the shoot length of germinated little millets for different time intervals at 5% level.

Vitamin C content of germinated little millets

The accumulation of ascorbic acid during sprouting in grains was due to reactivation of enzyme L-galactono-γ-lactone dehydrogenase, that involved in the oxidation of L-galactono-1,4-lactone to ascorbic acid[19]. The vitamin C content of little millets increased slowly up to 24 h (5.11 mg/100 g) and then decreased with increase in germination duration due to unavailability of glucose for further conversion to vitamin C as depicted in Figure 3A. The mean value of 12-48 h germinated little millets was 2.43 mg/100 g while non-germinated little millets possessed vitamin C of only 0.62 mg/100 g. There was statistically significant difference at $p \leq 0.05$ between the non-germinated and germinated little millets at different incubation times.

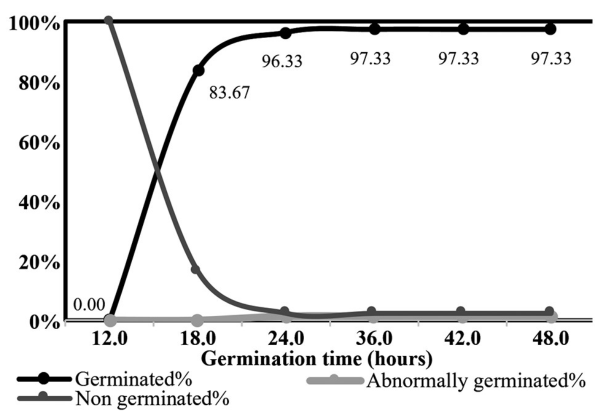

Fig. 1 — Germination percentage of little millets at different incubation times

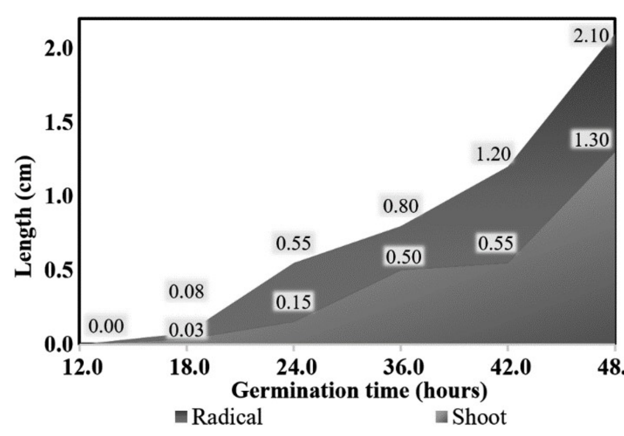

Fig. 2 — Radical and shoot lengths of germinated little millets

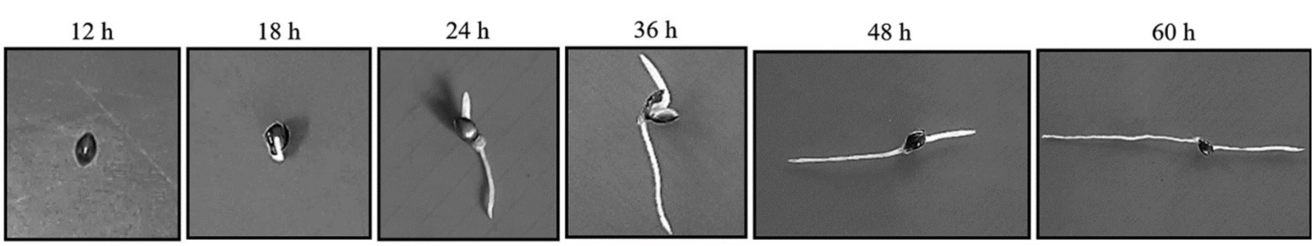

Plate 1 — Germinated little millet at different incubation times

α-amylase activity and total soluble solids content of germinated little millets

Germination enhanced α-amylase activity of little millets upto certain point and thereafter showed a declining trend with increase in time duration. The non-germinated little millets possessed low α-amylase content (0.31 μg/100 g), which was increased rapidly during germination upto 18 h (1.53 μg/100 g) and subsequently decreased as presented in Figure 3B. The mean value of 12-48 h germinated little millets was 0.84 μg/100 g. There was statistically ($p \leq 0.05$) significant difference between the non-germinated and germinated little millets at different time intervals. Likewise, α-amylase activity of finger millet increased rapidly upto 96 h germination at 37°C and subsequently decreased[20]. This is because during germination, gibberellic acid production by the embryo increased that diffused into endosperm and surrounding aleurone layers evoking rapid synthesis and secretion of hydrolytic enzymes like α-amylase that depolymerised stored macromolecules in starchy endosperm cells.

The non-germinated little millets had lower total soluble solids (TSS) content (0.83°Brix) but increased rapidly during germination upto 24 h (2.33°Brix) due to improved α-amylase activity and subsequently decreased due to utilisation by embryonic axis as depicted in Figure 3B. The mean value was 1.38°Brix and statistically significant difference was observed between non-germinated and germinated little millets from 18 h of incubation at 5% level. Thus, controlled germination of little millets is ideal to attain enzymatic activity with desirable level of degradation of complex components. This was found to be beneficial for designing low FODMAP (fermentable oligosaccharides, disaccharides, monosaccharides and polyols) diet for patients with irritable bowel syndrome by promoting their degradation in gluten free millets through enhanced hydrolytic enzymes activity[21].

Milling yield of germinated little millets

The whole little millets were tray dried at 60°C to obtain moisture content below 12.0% and dehulled in rubber roll sheller to remove the husk completely. The non-germinated little millets exhibited milling yield of 66.54% with husk per cent of 33.46%. The 12 h germinated little millets exhibited maximum milling yield of 73.03% with minimum husk per cent of

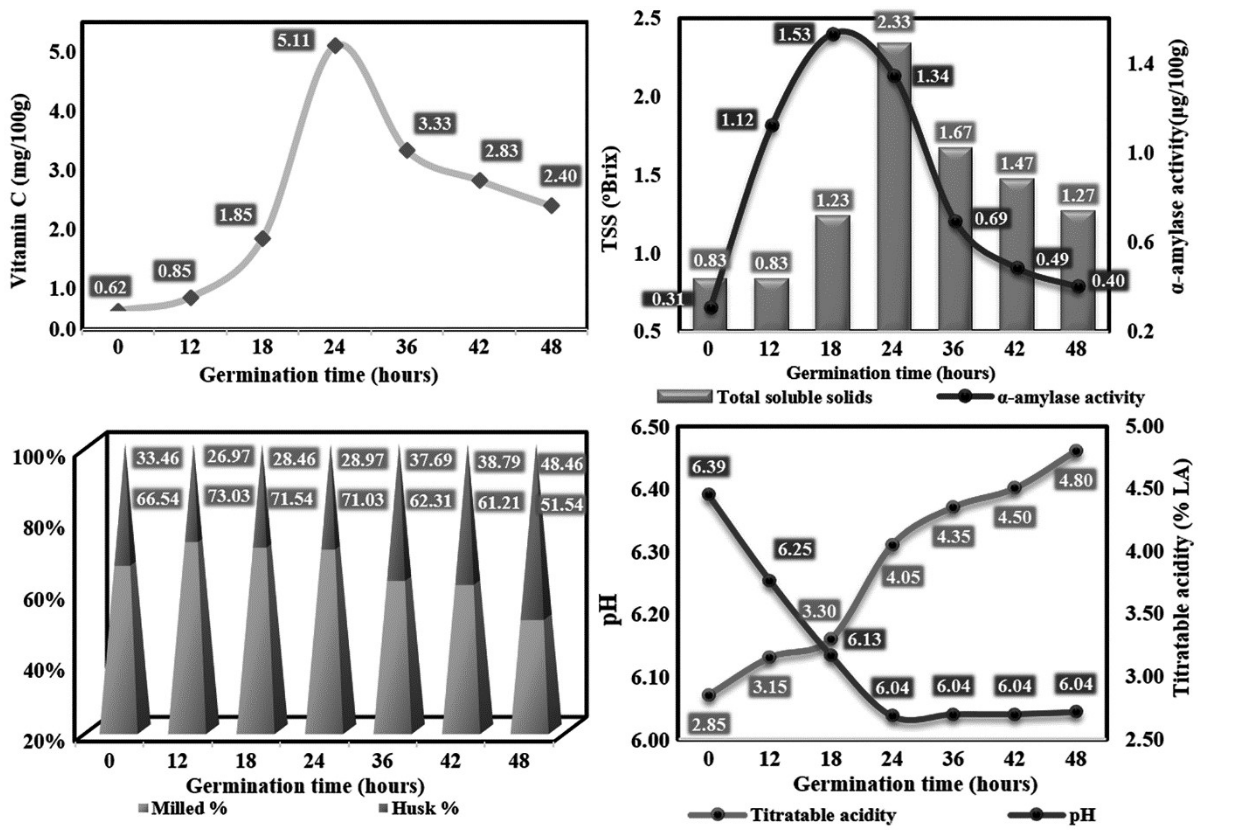

Fig. 3 — Effect of germination on A) vitamin C content B) α-amylase activity and total soluble solids C) milling yield D) pH and titratable acidity of little millets

26.97%. The mean value of 12-48 h germinated little millets for milling yield was 65.31% and for husk per cent was 34.69% (Fig. 3C). There was statistically significant difference at 5% level between non-germinated and germinated little millets at different intervals for milling yield and husk percentage. This might be due to easy removal of outer bran portions in germinated grains thereby reducing brokens content with high head millet yield compared to non-germinated ones.

The results were on par with findings of other researchers[22]where the milling yield of non-germinated and 18 h germinated little millets was 67.0 and 68.3%, respectively. Decortication is generally preferred for the reduction of antinutrients, hardness value, cooking time and enhancement of protein digestibility, starch digestibility, mineral availability, edibility and sensory properties of food grains[23].

Titratable acidity and pH of germinated little millets

Germination of little millets increased the titratable acidity and decreased pH (Fig. 3D) that could be associated with off flavours. Hence determination of ideal duration for germination is vital. The titratable acidity of non-germinated and 12 h germinated little millets were lowest with 2.85 and 3.15% lactic acid, respectively. Statistically significant difference was observed between non-germinated and germinated little millets at different time intervals at 5% level.

Similarly, the pH of non-germinated and 12 h germinated samples were highest with 6.39 and 6.25, respectively with statistically no significant difference between 24, 36, 42 and 48 h of germination at 5% level. As the germination time increased, the acidity of sample increased due to conversion of starch into lactic acid. During germination some complex organic molecules such as carbohydrates, lipids, phytins and protein were degraded to produce organic acids like fatty acids, amino acids and phytic acid which provided energy for seed growth[9].

Sensory parameters of cooked germinated little millets

The best score for appearance and texture of cooked little millets was for non-germinated and 12 h germinated samples with same score of 8.67 and 8.73 respectively followed by 18 and 24 h germinated with same score of 8.33 and 8.67 respectively on a hedonic scale. The flavour, taste and overall acceptability of cooked little millets improved as duration of germination increased to 24 h with a best score of 8.73 and thereafter declined might be due to increased production of fatty acids associated with high lipase activity resulting in off flavours[9].

The enhancement of flavour, taste and decline in appearance during germination might also be due to production of maltose, maltotriose and dextrin by starch hydrolysis due to increased amylolytic activity and Maillard reaction. The texture of cooked millets was positively correlated to adhesiveness, elasticity, apparent amylose content and negatively correlated with the hardness[24]. Thus, the fall in amylose activity with prolonged germination might result in decreased texture of germinated little millets.

The longer sprouting times make them desired units for use in traditional food processing due to high enzymatic activity to develop designer foods. Similar results were reported by other researchers[25] where the porridges made with 48 and 72 h germinated millet flours possessed darker colour, off flavour, bitter taste compared to 24 h germinated and non-germinated ones. It can be due to development of brown pigments (melanoidins) during oven drying after germination when the starch reacted with proteins through Maillard reaction.

Pearson correlation for different parameters of germinated little millets

The duration of germination was positively correlated to radicle length and titratable acidity whereas negatively to pH, texture and taste of cooked millets with $r = 0.90552$ at $p \leq 0.005$ and appearance of cooked millets with $r = 0.95087$ and $p \leq 0.001$. Further it was positively correlated to shoot length whereas negatively to milling yield, flavour and overall acceptability of cooked millets with $r = 0.75446$ at $p \leq 0.05$. The germination percentage was significantly correlated to vitamin C content with $r = 0.75446$ at $p \leq 0.05$. Hence, prolonged germination could comprise the nutritional and sensory profile of little millets. Likewise, other researchers[26] reported that duration of germination was positively correlated with titratable acidity and negatively correlated with pH of finger millet. Further, it was negatively correlated with the sensory attributes such as colour, taste, aroma, mouth feel and overall acceptability of germinated finger millet based porridges.

Selection of best germinated little millets

The vitamin C, TSS of germinated grains and overall acceptability of cooked ones were found to be highest at 24 h germination. In addition, there was good amount of α-amylase activity (1.34 μg/100 g), milling yield (71.03%), acceptable pH (6.04) and titratable acidity (0.04% lactic acid). Hence, 24 h germination of little millets was selected as best incubation time to carry out further analysis.

Physical parameters of germinated little millets

Colour

The L*, a* and b* units were often used in food research studies to determine the uniform distribution of colours as these units were very close to human colour perception. The germinated little millets had significantly higher L*, b*, E*, h* and lower a*, C* values of 23.23, 6.10, 34.51, 29.59, 30.21 and 11.66 respectively compared to non-germinated ones with 16.51, 4.29, 38.11, 30.01, 30.31 and 8.13, respectively representing lighter and less red coloured grains due to better removal of bran after germination. The differences in perceivable colour can be analytically classified as very distinct ($\Delta E > 3$), distinct ($1.5 < \Delta E < 3$) and small difference ($1.5 < \Delta E$)[27]. The total colour difference (ΔE^*) between non-germinated and germinated little millets was very distinct with a value of 6.98±0.07.

Microscopic dimensions

The change in dimensions of little millet upon germination was determined using stereo zoom microscope (Plate 2). The length, breadth, radius, perimeter and area of non-germinated little millets were 1.53 mm, 1.22 mm, 0.80 mm, 4.57 mm and 2.02 mm^2 respectively while that of germinated ones was 1.52 mm, 1.18 mm, 0.80 mm, 4.46 mm and 1.99 mm^2 respectively. There was statistically no significant difference at $p \leq 0.05$ between non-germinated and germinated little millets for all structural properties except perimeter. Germination resulted in decreased L/B ratio of little millets from 1.23 to 1.20 with a statistically no significant difference between them at $p \leq 0.05$.

Thousand grain weight and volume

The thousand grain weight and volume of germinated little millets with 1.09 g and 1.51 mL respectively which were significantly lesser than non-germinated ones with 1.23 g and 1.81 mL respectively as germination resulted in breakdown of complex components to simpler and easily digestible ones and drying of grains after germination. The findings were comparable to other researchers[28]where the thousand grain volume of improved variety of little millet (*Sukshema*) was 1.60 mL.

Bulk and tapped densities

The germinated little millets had lower bulk and tapped densities of 0.75 and 0.80 g/mL than non-germinated ones with 0.79 and 0.85 g/mL with statistically no significant difference at $p \leq 0.05$ between them. This might be due to loss of kernel shape, decreased L/B ratio and 1000 grain weight. The more round the kernel with high L/B ratio and 1000 grain weight, the greater will be the bulk density[29]. Similarly, germination of finger millet for 24 h resulted decrease in bulk density from 0.48 to 0.46 g/mL[30]. Thus, germinated little millets can be utilised for development of low bulk weaning foods for growing children. Other researchers[26,31,32] have also potentially utilised germinated grains for development of low bulk nutrient dense weaning and complementary mixes with improved sensory attributes for infants and young children to promote vital growth and combat malnutrition.

Hydration and swelling capacities

Germination significantly ($p \leq 0.05$) increased the hydration and swelling capacities of little millets from 0.70 to 0.88 g and 0.47 to 0.64 mL per thousand grains respectively. The presence of swelled starch fractions in germinated little millets due to starch hydrolysis by α-amylase activity than in non-germinated ones increased the hydration and swelling

Plate 2 — Microscopic dimensional analysis of little millets

capacities. Likewise, the hydration and swelling capacities of different varieties of 24 h germinated finger millets enhanced from 0.63-0.75 to 1.15-1.81 g and 1.25-1.80 to 2.50-2.90 mL, respectively[33].

Cooking quality of germinated little millets

The germinated little millets had significantly ($p \leq 0.05$) better water uptake ratio (4.13) than the non-germinated ones (4.02) and thus exhibited better elongation and volume expansion ratios. The cooked germinated little millets had good appearance with significantly ($p \leq 0.05$) high elongation ratio of 1.25 compared to non-germinated ones of 1.18. The lengthwise elongation gave finer appearance, which was more consumer acceptable than girth wise that results in coarser bulged look[34]. The volume expansion ratio of cooked millets improved significantly ($p \leq 0.05$) with germination from 3.80 to 5.29. The higher the volume expansion ratio, lower the energy content per unit volume or weight of cooked grains as they have more water and less solid content[35]. Thus, germinated little millets may provide comparatively less energy.

The cooking time is vital to determine the tenderness of cooked grains as well as its stickiness. Rapid cooking was considered beneficial, as the grains will not be exposed to high temperature for long duration causing protein degradation. Germinated little millets required significantly ($p \leq 0.05$) less cooking time (15.53 min) compared to non-germinated ones (22.82 min) due to decreased grain hardness, comparatively porous grain structure allowing faster diffusion of water into kernels and easy dissociation of complex nutrients. The results obtained were on par with the findings of other researchers[36] where the cooking time of hydrothermally treated little millets varied from 15.00 to 28.73 min depending on the soaking and steaming temperatures.

The germinated little millets exhibited significantly ($p \leq 0.05$) more gruel solid loss (24.99%) than the non-germinated ones (10.09%). This was due to saccharification of complex carbohydrates resulting in simpler ones which can easily leach out of the kernel into gruel. The colour of gruel was slightly cream indicating the solubilisation of some constituents from endosperm. The breakdown of complex carbohydrates made germinated little millets ideal for preparation of weaning and complementary mixes with better digestibility. The equivalent weight of cooked little millets was significantly ($p \leq 0.05$) lower for germinated ones (665.55 g/100 g) than the non-germinated ones (771.46 g/100 g) due to structural changes in grains with germination. The results indicated that non-germinated and germinated little millets gained weight by 7.7 and 6.7 times respectively upon cooking. The solid content of cooked little millets was also significantly ($p \leq 0.05$) lower for germinated ones (568.42 g) compared to non-germinated ones (682.27 g) due to more gruel solid loss.

Gelatinization temperature represents the structural stability of starch molecules. Higher the alkali degradation, lower will be the gelatinization temperature[34]. The gelatinization of starch present in the grains determines the product quality during baking and extrusion indicating its effectiveness as gelling or thickening agent in different food products[37]. The germinated little millets exhibited significantly ($p \leq 0.05$) higher alkali degradation (2.67) and lower gelatinization temperature (61.0°C) compared to non-germinated ones (1.33 and 76.5°C), respectively indicating greater disassociation of starch granular structure associated with enzymatic activity and thus ease of cooking of germinated little millets. Further, grains with low gelatinization temperature elongates better during cooking[34] and thus germinated little millets exhibited better volume expansion ratio.

The extent of starch changes during gelatinization and retro gradation were major determinants of its functional properties during digestion and food processing[38]. The native, pregelatinised, gelatinised and retrograded starches of both non-germinated and germinated little millets were visualised under Lawrence and Mayo binocular microscope to interpret the structural changes under hydrothermal treatment as depicted in Plate 3. The native starches of both non-germinated and germinated little millets had clearly demarcated granules with semi crystalline and amorphous form. However, germinated ones had large number of swollen granules with increased compactness than non-germinated ones. When these native starches were subjected to hydrothermal treatment and pregelatinised, the granules hydrated, swollen to greater extent and were no more intact. Gelatinisation of starches led to breakdown of hydrogen bonds resulting in loss of birefringence, starch solubilisation and transformation into viscous paste. Upon cooling, the gelatinized starches the disintegrated starch chains realigned into partially ordered structures that differed from those of native granules resulting retrograded starches.

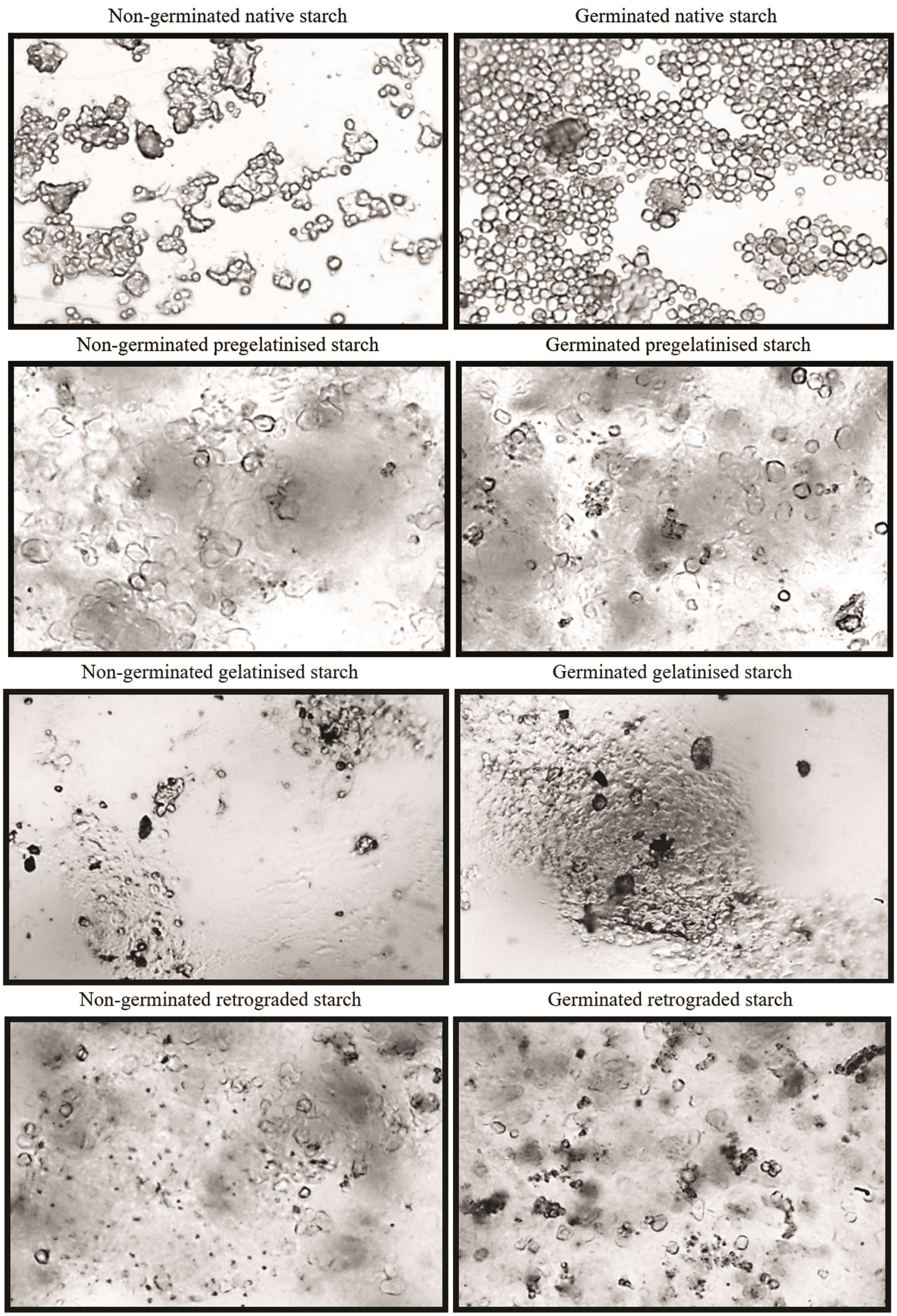

Plate 3 — Microscopic structure of little millet starches

Nutritional characteristics of germinated little millets

The moisture content of non-germinated and germinated little millets was 9.85 g/100 g and 9.28 g/100 g respectively. The significant decline in moisture content was due to drying of germinated grains. Germination improved ash (total mineral), protein and crude fiber contents of little millets from 0.52 to 1.20 g/100 g, 7.95 to 8.50 g/100 g and 4.87 to 6.18 g/100 g, respectively as activated enzymes freed the bonds between minerals, protein and other compounds enhancing bioavailability of minerals, synthesised new amino acids and structural carbohydrates like cellulose, hemi-cellulose and lignin during plant elongation[39-41].

Further, germination resulted in significant reduction of fat and energy content of little millets from 4.62 to 1.58 g/100 g and 362 to 341 Kcal/100 g, respectively due to conversion into fatty acids for use as energy source during this process causing shift in nutrient profile, which is beneficial for designing low-energy therapeutic foods. The carbohydrates content of non-germinated and germinated little millets was 72.19 g/100 g and 73.26 g/100 g, respectively. The decrease in the starch content during germination was not totally reflected in the total carbohydrate content due to the partial compensation by simple sugars derived from starch[42].

The per cent adequacy of nutrients provided by consumption of one serving of germinated little millets (75 g cooked with 300 mL water) as per NIN (2020) recommendations was determined. It could meet 12.1 and 15.4% of energy, 36.9 and 36.9% of carbohydrates, 11.8 and 13.9% of protein, 5.9 and 5.9% of fat, 14.5 and 18.5% of fiber requirements of sedentary adult men and women respectively. As per FSSAI (2022) regulations, the foods providing protein minimum of 10% RDA per serving and fiber minimum of 6 g per 100 g can be claimed as good source. Thus, germinated little millets were found to be good source of protein and fiber and beneficial for obese and diabetic people.

Germination of little millets improved the total and non-reducing sugars content from 11.51 to 14.80 g/100 g and 10.62 to 13.96 g/100 g, respectively while decreased the reducing sugars content from 0.89 to 0.86 g/100 g. The elevation in total sugars content in germinated little millets was due to degradation of starch in endosperm during germination. Further, the increased non-reducing sugars content in them was due to presence of more disaccharides that do not undergo chemical reactions and can be protective to seeds during abiotic stresses like heat, drought, high salinity and UV rays[43].

Conclusions

The 24 h germinated little millets were found be better source of vitamin C, α-amylase activity, total soluble solids with improved milling yield and overall acceptability for cooked millets compared to non-germinated ones. Germination has also enhanced the hydration, swelling capacities, water uptake ratio, elongation ratio, volume expansion ratio and decreased the bulk density, tapped density, cooking time, gelatinisation temperature, solid content of little millets due to saccharification of complex carbohydrates into simpler ones. Further, it improved protein, crude fiber, total mineral contents and reduced moisture, fat, energy, reducing sugar contents due to activation of metabolic machineries which promoted synthesis and release of bound components by reducing antinutrients. Thus, controlled germination of little millets could be an effective approach to enhance their cooking, sensory and nutritional quality and promote utilisation as functional ingredients for formulation of cost-effective low bulk weaning and complementary mixes for infants and young children or novel nourishing convenience foods for globetrotting and fast paced lifestyle consumers.

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Conflict of Interest

There is no conflict of interest declared by the authors.

Author Contributions

JSW conceived and presented the idea. BN performed the experimentation, wrote the original manuscript, reviewed, edited and conducted the statistical analysis of data.

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