Exploring the functionality of ethnic fermented sour beverages and their standardization with improved shelf stability for industrial use

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Abstract
The nutritional and functional characteristics of cereal and millets have been enhanced by fermentation technology and have proven to be a viable option for the cereal industry. The fermentation technique aids in increasing the nutrient content, viz., minerals, vitamins, proteins, phenolics and antinutritional compounds, as phytic acid degrades. The study aimed to investigate the appropriate fermentation technique for developing ethnic fermented sour beverages and standardize the product with improved shelf stability for industrial use. Neeragarams (an indigenous fermented rice product from the southern part of India) were prepared using Mapillai samba, and a notable and nutritious traditional rice variety of Tamil Nadu was taken (T1 - raw - unpolished, T2 - raw - polished, T3 - parboiled - unpolished and T4 - parboiled - polished) with added species such as onions, green chillies and curry leaves. The study observed that among four different treatments of neeragaram, T1 (raw rice - unpolished) was highly acceptable based on consumer acceptability with the sensory value of 9.0 higher nutritional characteristics viz., energy 68.29 Kcal, carbohydrates 11.15 %, protein 4.21 %, fat 0.93 %, iron 4.21 mg, potassium 181.7 mg, sodium 61.23 mg and zinc 2.32 mg per 100 ml of neeragaram. The developed product will be highly suitable for commercialization with improved shelf stability. Among the four treatments, raw (unpolished) neeragaram was highly acceptable with maximum retention of nutritional characteristics. The developed fermented sour beverages do not involve a high cost of production and earn good returns to entrepreneurs. The development of these fermented sour beverages using rice will increase the suitability for consumers and, in turn, improve persons with nutritional and functional status.

Keywords: Fermentation, Nutritional characteristics, Shelf stability, Traditional rice, Human health

INTRODUCTION
The most common cereal consumed by people is rice, and it is a staple food for approximately half of the world population. Approximately 50,000 varieties of rice existed before 400 BC, but now only a few varieties are cultivated by the human population. Worldwide, India places 2nd in rice cultivation, with a total area of approximately 59.6 million hectares and a production yield of 4.6 tons per hectare (Oko et al., 2019). After the Green
Revolution, the net availability of food grains per capita was amplified to 71.9 kg/year in 2020 from 62.5 kg/year in 1951. The primary food for the Indian population is rice, and 90% of the people consume rice as their staple food. Compared to polished white rice, traditional brown rice varieties are higher in nutrients and hold major health benefits (Rayaguru et al., 2011). Many types of ethnic fermented cereal foods are widely consumed worldwide. In fermented food preparation, beneficial microbes have an essential role in improving the sensory quality, nutritional value, prevention of health-causing diseases and protection of foods. In Tamil Nadu, the traditional practice is the consumption of fermented rice by the majority of people. Fermented rice was traditionally prepared by allowing the excess cooked rice to ferment overnight and added curd at a small amount and then consuming the fermented rice the next day. This is one of the best techniques to conserve food resources without wastage. The leftover cooked rice allowed for fermentation was known as ‘pazhaya sadham’ or ‘palaya soru’, and fermented rice water was known as pazhaya sadham kanchi or neeragaram. Extracts obtained from rice are an alternative beverage for consuming healthy products with desirable nutritional characteristics. Epidemiological studies consistently showed that the consumption of fermented cereal products drastically reduced the onset of type II diabetes, ulcers, and coronary heart diseases. Haard et al. (2019) stated that the natural fermentation of cereals breaks down complex carbohydrates to simple sugars, synthesizes amino acids and increases the bioavailability of B vitamins and minerals. The most favourable pH condition leads to the degradation of antinutritional factors and increases the bioavailability of minerals, viz., iron, zinc and calcium (Nout and Motarjemi, 2017).

Sour beverages fermented using traditional rice enhance the body with a high-energy rich rehydrating drink, refurbish health with beneficial intestinal flora, help to prevent the occurrence of gastrointestinal diseases and promote immune barriers, which are the most promising solutions to decrease the prevalence of health ailments. It acts as an emerging demand for market among non-dairy probiotic beverages. Short-chain fatty acid (SCFA) molecules present in torani (Neeragaram) in good proportion have anti-inflammatory properties. “Lactobacillus in ‘torani’ promotes secretory immunoglobulins that fight local infection, particularly in the lungs and intestines”. SCFAs have multiple functions in our body. These are energy sources and have antiviral properties (Balamurugan, 2021). The study aimed to develop the ethnic fermented sour beverages using traditional rice variety and analyze their nutritional characteristics.

**MATERIALS AND METHODS**

The Mapillai samba paddy was procured from Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu. This traditional rice variety was chosen based on consumer preference and is popularly cultivated in southern India. The different treatments, such as raw rice (unpolished, polished) and parboiled rice (unpolished, polished), were performed at the Department of Food Science and Nutrition, Community Science College and Research Institute, Tamil Nadu Agricultural University, Madurai. The paddy was hulled using a huller machine, milled rice using a polisher machine for one min/100 g of rice, and paddy parboiling was performed using the Central Food Technological Research Institute method. Then the rice samples were stored in an airtight container for further biochemical analysis. Mud pots were used for fermenting cooked rice.

**Standardization of process parameters for the development of neeragaram**

The rice variety utilized in the study is represented in (Fig. 1). The fermented sour beverages (neeragaram) were prepared using the traditional rice Mapillai samba.
The different treatments were raw rice (unpolished, polished) and parboiled rice (unpolished, polished) for the processing of neeragaram, as presented in Table 1. Fermentation was carried out in an incubator at 30°C overnight. The known weight of rice (100 g) was taken, and 300 ml of water was added and allowed to cook for approximately 20 mins. Then, cooked rice was added along with the required amount of water, and different spices, such as green chillies (5 g), small onions (20 g), curry leaves and coriander leaves (1 g), in a mud pot were allowed to ferment overnight in an incubator at 30°C. The hulling and milling characteristics were analyzed by the Association of Official Analytical Chemists method (AOAC 2000). Physical characteristics such as length, breadth, length/breadth ratio, thousand grain weight and gruel solid loss were analyzed using the AOAC method (2000). Nutritional characteristics such as energy, carbohydrates, protein, fat, fiber and minerals such as iron, potassium, sodium and zinc were analyzed using the AOAC method (2005).

Parboiling of paddy

The initial moisture content of paddy was 13±1% w.b. Paddy parboiling was conducted by the CFTRI method. A cleaned paddy sample (one kg) was soaked in 1250 ml of hot water at 70°C for three hours. Then, the water was drained off and allowed to steam for approximately 20 mins. Again, the steaming water was drained away, allowing steaming using a 1.05 kg/cm² vertical autoclave (15 psi) for approximately 30 mins. After steaming, paddies were sun-dried for 4 hrs, and the optimum moisture content was approximately 13-14% (w.b.) which was appropriate for milling of the paddy.

Hulling and Milling of paddy

A total of 500 g of all treatments (raw and parboiled paddy samples) was dehulled using Satake huller cum rubber roll sheller THU (No. 101527) (Satake Engineering Co. Ltd. Tokyo, Japan) in two passes and for polishing the raw and parboiled rice polished in a horizontal abrasive type polisher for one minute by using a Satake grain testing mill (No. 553228, Satake Engg Co Ltd, Tokyo, Japan).

Physico-chemical characteristics of selected rice variety

Length, breadth, length/breadth ratio

The length, breadth and L/B ratio were analyzed (Odenigbo et al., 2014) for the rice samples. Ten rice kernels were taken, and the length and breadth were noted using a Vernier calliper for all the treatments and expressed in cm.

Thousand grains weight

An electronic weighing balance was used to determine thousand-grain weights (Odenigbo et al., 2014).

Gruel solid loss

The gruel solid loss of the samples was analyzed according to the method (Ayamdoo et al., 2014).

Gruel solid loss (%) = Increase in weight of dish × 100/Weight of rice sample

Energy

The energy values of the selected rice samples for all the treatments were determined using the bomb Calorimetric method (AOAC, 2000).

Total carbohydrates

The total carbohydrates were estimated using the phenol-sulfuric acid method (AOAC, 2000) for the selected rice samples.

Protein

The amount of crude protein was analyzed by the

![Cooked Rice](image1)

![Fermentation](image2)

![Fermented Sour Beverage](image3)

**Table 1.** Different treatments of Neeragaram (Mapillai Samba)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Treatments</th>
<th>Rice variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>T1</td>
<td>Raw rice (Unpolished)</td>
</tr>
<tr>
<td>2.</td>
<td>T2</td>
<td>Raw rice (Polished)</td>
</tr>
<tr>
<td>3.</td>
<td>T3</td>
<td>Parboiled rice (Unpolished)</td>
</tr>
<tr>
<td>4.</td>
<td>T4</td>
<td>Parboiled rice (Polished)</td>
</tr>
</tbody>
</table>

Fig. 3. Preparation of fermented sour beverage (Neeragaram)
higher hulling and milling recovery and reduces (2016) stated that raw rice leads to kernel integration, length, breadth, L/B ratio and thickness was noted in percentage of parboiled rice (68.6%) was higher than yield compared to raw rice. Accordingly, the milling parboiling process obtained the maximum head rice presented in Table 2. The hulling recovery was higher The hulling and milling characteristics of the paddy are

RESULTS AND DISCUSSION

Gomez (1984) using AGREE statistical software. randomized design (CRD) proposed by Gomez and SPSS software (2017 version) and the completely ran- e

to assess the sensory properties using a score card

Organoleptic evaluation

A panel of fifteen semitrained judges evaluated organoleptic evaluation for the developed sour beverages to assess the sensory properties using a score card with a nine-point hedonic scale. The panellists determined the quality of developed sour beverages in terms of appearance and color, flavor, consistency, taste and overall acceptability (Wichchukit and O’Mahony, 2015). Statistical analysis

The data obtained from the studies were recorded and subjected to statistical analysis. The significance effect between different parameters for the selected rice variety and its treatments was analyzed by means of SPSS software (2017 version) and the completely randomized design (CRD) proposed by Gomez and Gomez (1984) using AGREE statistical software.

Fat

The amount of fat content in selected rice samples was analyzed using a Socs plus apparatus (Pelican Equip- ments, SCS-08, Chennai, India).

Fiber

The crude fiber content was determined by the method described by (Maynard, 1995) using fibra plus.

Total amylose

The amylose content present in the selected rice sam- ples was analyzed using potato amylase as a standard (Bhattacharya and Sowbhagya, 1971).

Estimation of minerals

The mineral content present in the selected rice sam- ples was estimated using atomic absorption spectrophotometry following the method of Lindsey and Nor- well (1969).

Organoleptic evaluation

A panel of fifteen semitrained judges evaluated organo-lectic evaluation for the developed sour beverages to assess the sensory properties using a score card

Statistical analysis

The data obtained from the studies were recorded and subjected to statistical analysis. The significance effect between different parameters for the selected rice variety and its treatments was analyzed by means of SPSS software (2017 version) and the completely randomized design (CRD) proposed by Gomez and Gomez (1984) using AGREE statistical software.

RESULTS AND DISCUSSION

The hulling and milling characteristics of the paddy are presented in Table 2. The hulling recovery was higher in parboiled rice (79.1%) than in raw rice (76.1%). The parboiling process obtained the maximum head rice yield compared to raw rice. Accordingly, the milling percentage of parboiled rice (68.6%) was higher than that of raw rice (67.6%). The maximum increase in length, breadth, L/B ratio and thickness was noted in the parboiling process (Saif et al., 2019). Bhattacharya (2016) stated that raw rice leads to kernel integration, higher hulling and milling recovery and reduces cooking loss. The physical characteristics estimated for the selected rice samples, viz., length, breadth, L/B ratio, thousand grain weight and gruel solid loss, to check the signifi- cant effect (p > 0.05) among the rice varieties and are illustrated in Table 3. The data from the study revealed that the conventional rice variety Mapillai samba, parboiled - unpolished rice showed the highest length of 0.59 cm with a breadth of 1.92 cm followed by raw - unpolished rice. The thousand grain weight was higher for parboiled - unpolished plants (26.7 g), followed by other treatments. Raw polished rice has gained popu- larity for greater L/B ratios. However, it decreased from 3.23 for raw polished rice to 3.03 for sample parboiled - polished rice. The data obtained from the treatments were similar to the study conducted by Odenigbo et al., (2014), who estimated the length, breadth and L/B ratios of parboiled and raw rice varieties of karungkuruvai milled rice. The length of local rice varieties was maxi- mum compared to traditional rice varieties (Raghuvanshi et al., 2017).

Parboiling reduced the amount of solid dissolution into the cooking water. The maximum gruel solid loss in the parboiled rice treatment was 2.59%, which significantly decreased (p<0.05) to 2.10% in the raw rice treatment, indicating that all rice treatments had a negative correlation with cooking time (R²=0.90). Soponronnarit et al., (2019) reported that minimum gruel solid loss would lead to a vigorous rice structure influenced by starch gelatinization. The cooking and pasting characteristics were deter- mined by the level of amylose content present in the rice varieties. The data revealed a significant (p<0.05) reduction in the parboiled polished rice sample from 25.9% to 23.4% in raw unpolished rice (Asghar et al., 2020). Rice containing intermediate amylose content (20-25%) cooks moist and soft and is consumed more widely than rice with high (>25%) or low amylose content (10-20%) (International Rice Research Institute, 2017). The nutritional characteristics of neeragaram are pre- sented in (Table 4 and Fig. 4). Among all the treat- ments, the raw - unpolished rice variety neeragaram had higher nutritional characteristics. The maximum total energy was 68.29±0.25 kcal in raw unpolished rice and 51.29±0.49 kcal in parboiled polished rice. Raghuvanshi et al., (2017) reported an energy value of 49.34 kcal in neeragaram prepared using local rice va- rieties. Treatment T₁ possessed a maximum carbohy- drate content of 11.15±0.88 % and a minimum carbo- hydrate content in T₄ of 8.16±0.42 %. The total protein content was higher in T₂ (4.21±0.11 %) than in the oth- er treatments T₃ (4.09±0.41 %), T₂ (3.80±0.26 %) and T₄ (3.72±0.30 %). The maximum fiber content was observed in T₁ at
The mineral content was analyzed for all the treatments. The developed fermented sour beverages of T1 had higher mineral contents of 4.21 mg, 181.7 mg, 61.23 mg and 2.32 mg of iron, potassium, sodium and zinc per 100 ml, respectively, followed by other treatments. Fermented sour beverages will replace carbonated beverages with additional nutritional value, replenish them with higher mineral-rich energy drinks and help in the maintenance of body functioning. The results were similar to the study conducted by Praveen Kumar et al., (2018) and they stated that mineral analysis of fermented rice had iron 0.20 mg, potassium 2.93 mg, sodium 1.36 mg per 10 g. The scores of organoleptic evaluations performed for the developed fermented sour beverages by semi-

Table 2. Hulling and Milling characteristics of paddy

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Rice varieties</th>
<th>Hulling (g)</th>
<th>Husk (g)</th>
<th>Milled rice (g)</th>
<th>Bran (g)</th>
<th>Hulling Percentage (%)</th>
<th>Milling Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Raw - Mapillai Samba</td>
<td>74.9</td>
<td>23.4</td>
<td>58.3</td>
<td>2.7</td>
<td>76.1</td>
<td>67.6</td>
</tr>
<tr>
<td>2.</td>
<td>Parboiled - Mapillai Samba</td>
<td>78.4</td>
<td>23.6</td>
<td>59.7</td>
<td>2.4</td>
<td>79.1</td>
<td>68.6</td>
</tr>
</tbody>
</table>

Table 3. Physico-chemical characteristics of selected rice variety (Mapillai Samba)

| S.No. | Treatments                      | Length (mm) | Breadth (mm) | L/B ratio | 1000 grain weight (g) | Gruel solid loss (%) | Amylose (%) | Amylopectin (%) |
|-------|--------------------------------|-------------|--------------|-----------|-----------------------|---------------------|-------------|----------------|---------------|
| 1.    | Raw-Unpolished-Mapillai Samba  | 0.57        | 0.18         | 3.17      | 24.1                  | 2.28                | 23.4        | 76.6            |              |
| 2.    | Raw-Polished-Mapillai Samba    | 0.55        | 0.17         | 3.23      | 22.5                  | 2.10                | 23.9        | 76.1            |              |
| 3.    | Parboiled-Unpolished-Mapillai Samba | 0.59       | 0.19         | 3.05      | 26.7                  | 2.59                | 25.2        | 74.8            |              |
| 4.    | Parboiled-Polished-Mapillai Samba | 0.56       | 0.18         | 3.03      | 24.8                  | 2.43                | 25.9        | 74.1            |              |
| CD (5%) |                                 | 0.04        | 0.05         | 0.34      | 0.27                  | 0.26                | 0.57        | 0.49            |              |

Table 4. Nutritional characteristics of neeragaram

<table>
<thead>
<tr>
<th>S.No</th>
<th>Nutrients</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Energy (Kcal)</td>
<td>68.29 ± 0.25^a</td>
<td>59.02 ± 0.29^b</td>
<td>57.15 ± 0.31^c</td>
<td>51.29 ± 0.49^d</td>
</tr>
<tr>
<td>2.</td>
<td>Carbohydrates (%)</td>
<td>11.15 ± 0.88^a</td>
<td>9.03 ± 0.98^b</td>
<td>10.59 ± 0.86^b</td>
<td>8.16 ± 0.42^d</td>
</tr>
<tr>
<td>3.</td>
<td>Protein (%)</td>
<td>4.21 ± 0.11^a</td>
<td>3.80 ± 0.26^c</td>
<td>4.09 ± 0.41^b</td>
<td>3.72 ± 0.30^d</td>
</tr>
<tr>
<td>4.</td>
<td>Fiber (%)</td>
<td>2.59 ± 0.53^a</td>
<td>1.25 ± 0.32^d</td>
<td>2.28 ± 0.32^b</td>
<td>1.26 ± 0.36^c</td>
</tr>
<tr>
<td>5.</td>
<td>Fat (%)</td>
<td>0.93 ± 0.57^d</td>
<td>0.71 ± 0.09^c</td>
<td>0.82 ± 0.57^c</td>
<td>0.66 ± 0.11^a</td>
</tr>
<tr>
<td>6.</td>
<td>Iron (mg)</td>
<td>4.21 ± 0.41^a</td>
<td>3.80 ± 0.26^c</td>
<td>3.98 ± 0.33^b</td>
<td>3.62 ± 0.37^d</td>
</tr>
<tr>
<td>7.</td>
<td>Potassium (mg)</td>
<td>181.7 ± 0.21^a</td>
<td>172.0 ± 0.19^b</td>
<td>152.6 ± 0.25^c</td>
<td>143.2 ± 0.16^d</td>
</tr>
<tr>
<td>8.</td>
<td>Sodium (mg)</td>
<td>61.23 ± 0.13^b</td>
<td>62.76 ± 0.11^a</td>
<td>56.45 ± 0.16^d</td>
<td>58.89 ± 0.22^c</td>
</tr>
<tr>
<td>9.</td>
<td>Zinc (mg)</td>
<td>2.32 ± 0.24^a</td>
<td>1.89 ± 0.35^c</td>
<td>2.10 ± 0.28^b</td>
<td>1.76 ± 0.15^d</td>
</tr>
</tbody>
</table>

approximately 2.59±0.53 %, followed by the other treatments, T2 at 1.25±0.32 %, T3 at 2.28±0.32 % and T4 at 1.26±0.36 %. Fat contents of 0.66±0.11 %, 0.71±0.09 % and 0.82±0.57 % were noted in the T2, T3 and T3 rice varieties, and a higher fat content was observed in T4 (0.93±0.57 %). The results showed that the protein and fat content decrease might be due to polishing treatment because the protein and fat content is present in the bran layer (Devika et al., 2017). The data revealed that this result was similar to the results observed by Saikia et al., (2014), who reported that the fat content ranged from 1.00 to 2.10/100 g in nonpigmented and pigmented indigenous rice varieties of Assam and Manipur.

The mineral content was analyzed for all the treatments. The developed fermente dogs had higher mineral contents of 4.21 mg, 181.7 mg, 61.23 mg and 2.32 mg of iron, potassium, sodium and zinc per 100 ml, respectively, followed by other treatments. Fermented sour beverages will replace carbonated beverages with additional nutritional value, replenish them with higher mineral-rich energy drinks and help in the maintenance of body functioning. The results were similar to the study conducted by Praveen Kumar et al., (2018) and they stated that mineral analysis of fermented rice had iron 0.20 mg, potassium 2.93 mg, sodium 1.36 mg per 10 g. The scores of organoleptic evaluations performed for the developed fermented sour beverages by semi-

Table 5. Score card for the organoleptic evaluation of Mapillai samba neeragaram

<table>
<thead>
<tr>
<th>Sensory characteristics</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance &amp; Color</td>
<td>8.5</td>
<td>8.2</td>
<td>8.4</td>
<td>8.2</td>
</tr>
<tr>
<td>Flavor</td>
<td>9.0</td>
<td>8.1</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Consistency</td>
<td>9.0</td>
<td>8.5</td>
<td>8.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Taste</td>
<td>9.0</td>
<td>8.3</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>9.0</td>
<td>8.3</td>
<td>8.2</td>
<td>8.1</td>
</tr>
</tbody>
</table>
trained panellists are depicted in Table 5 and Fig. 5. Of the different treatments, raw-unpolished-Mapillai samba neeragaram scored the highest overall acceptability of 9.0, followed by raw-polished, parboiled-unpolished and parboiled-polished. The observed data were in accordance with the results obtained by Simonelli et al. (2017), and they reported that among 10 different Italian rice varieties, the sensory profiles of Gange and Selenio aromatic rice varieties were highly accepted by the consumers.

Conclusion

The present study concluded that among different treatments of fermented sour beverages (neeragaram), mapillai samba raw unpolished (T₁) showed a significant increase in the nutritional characteristics and overall acceptability. The neeragaram has been developed by the natural fermentation method and it helps in increasing the protein and mineral contents. It acts as a probiotic source and produces short-chain fatty acids in the human intestine and also helps to heal stomach related disorders. India is considered the rice bowl of diversity. Traditional rice varieties are regarded as ethnic practice in medicine by many religious people, and they possess several health effects on the human body apart from the scientific world prevailing now. The cultivation of indigenous rice varieties in Tamil Nadu should consequently be increased for the consumption level among the population. The nutrient content was higher for indigenous rice varieties than for genetically modified ones. The optimum pH of the developed neeragaram helps to maintain hair density, enhance skin elasticity and decrease skin surface friction. There are only few relevant studies on fermented sour beverages' chemical and microbiological aspects. Thus, the present study evolves the nutritional characteristics of neeragaram to community health with all benefits.

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Conflict of interest

The authors declare that they have no conflict of interest.

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