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**Sushmita Mandal**
Department of Food Safety and Quality Assurance, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

**Dr. Suresh Kumar Kalakandan**
Professor and Head, Department of Food Safety and Quality Assurance, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

**V Hema**
Department of Food Plant Operation, Incubation and Entrepreneurship, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

**V Eyarkai Nambi**
Department of Food Plant Operation, Incubation and Entrepreneurship, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

**M Tito Anand**
Department of Food Process Engineering, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

**Suman Thamburaj**
Food Testing Laboratory, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

**Corresponding Author:**
**Dr. Suresh Kumar Kalakandan**
Professor and Head, Department of Food Safety and Quality Assurance, National Institute of Food Technology, Entrepreneurship and Management, (Formerly IIFPT), Ministry of Food Processing Industries, Government of India, Pudukkottai Road, Thanjavur, Tamil Nadu, India

# Effect of cooking methods on nutritional components and quality attribute of pearl millet flour porridge

**Sushmita Mandal, Suresh Kumar Kalakandan, V Hema, V Eyarkai Nambi, M Tito Anand and Suman Thamburaj**

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**Abstract**
In this study, the functional properties of pearl millet flour and nutritional components, quality characteristics of uncooked, conventionally, pressure, microwave, and machine-cooked porridge were analysed. The functional properties showed pearl millet flour exhibits good hydrating properties and dispersibility (71±1%) contributing to the even mixing and preparation of high-quality porridge. The result showed that machine-cooked porridge consists of high crude protein (5.085±0.04%) and fat (5.498±0.14%) content. The content of ash (2.551±0.03%) and crud fibre (3.109±0.05%) were highest in microwave-oven cooked porridge sample. The machine-cooked porridge sample showed high phenolic (70.807±2.97 mg GAE/100 g), flavonoids (58.412±2.38 mg RE/100 g) content, and DPPH radical scavenging activity of (75.677±0.49%). The pressure-cooked porridge sample consists of low moisture (71.184±0.09%) and water activity (0.980±0.03), indicating low available free water for bacterial and yeast proliferation. There was no microbial load for machine-cooked porridge samples due to high-temperature treatment, stirring mechanism, and closed environment that prevents cold, hot spots with uniform heating. The results obtained from optimized cooking methods recommended that machine and microwave cooking techniques are ideal for the production of good quality porridge with high nutritional and polyphenolic content.

**Keywords:** Pearl millet porridge, electric cookers, microwave ovens, nutritional properties, polyphenolic content, quality attribute

## 1. Introduction

Pearl millet (*Pennisetum glaucum*) is superior to major cereals and contains high nutrients such as protein (9-13%), crude fibre (2.7-4.2%), fat (4.8-8%) ash (1.7-2.4%), carbohydrate (66.49-68.85%) and minerals such as vitamin B, calcium (11.4-18.542 mg $kg^{-1}$), iron (42 mg $kg^{-1}$) phosphorus (328.7%) and zinc (32 mg $kg^{-1}$) [1]. This gluten-free grain is generally pulverized into flour and consumed as fermented bread, thick porridge, non-alcoholic beverages, steamed dishes, and snacks [2]. Among the consumption forms usually pearl millet is cooked into thick and thin porridge [3].

Pearl millet flour porridge contains nutrients that boost and lower glycaemic index, slow carbohydrate release, sustain energy levels, and improve blood sugar. It consists of nutritional components such as protein (5 g/100 g), fat (1.7 g/100 g), carbohydrate (27 g/100 g) and energy (180 Kcal/100 g). In previous studies, it was reported regular consumption of pearl millet porridge lowers postprandial blood glucose and appetite when compared with other grain [4]. The fibre content promotes digestion and gut health potentially alleviating constipation on regular feeding and improves the gastrointestinal function of model mice to a certain extent on regular consumption of millet porridge. It was also reported that millet porridge exhibits a glycaemic index of 70% which is considered high in diet, while the glycaemic load is equal to 18.9% which is consider moderate for food [5].

Cooking millet flour porridge is more complex than cooking rice and wheat porridge, including solid and liquid components. In this process, flour granules absorb water and swell, starch is heated, gelatinized, and cooled to form a gelling system [6] Traditional household cooking methods include boiling, which results in changes to its physical, functional, sensory, and biochemical properties and microbial contamination [7]. However, traditional cooking methods rely on convection and conduction mechanisms that reduce nutritional components due to prolonged cooking time and uncontrolled temperature that burns porridge, especially at the base due to excess heating. Therefore, with time inception of millet porridge-making machines, electric cookers, and microwave ovens has revolutionized commercial and household cooking methods extensively making them a promising option for the future [8].

Electric cookers primarily heat food through direct contact with heating elements which generate heat through resistance, whereas microwave ovens heat slurry by stimulating water molecules with electromagnetic radiation that vibrate them and generate heat through friction resulting in temperature rise and energy conservation by reducing cooking time [9, 10]. A study was conducted on the impact of microwave and pressure cooking on legumes. It was found that pressure cooking was more effective in the retention of protein, thiamine, riboflavin, amino acids, and pyridoxine content when compared with microwave-cooked samples. Similarly, a study was performed on comparing microwave and conventional cooking methods on the nutritional content of cooked cowpea and zhinggye. The study reported that microwave-cooked samples showed retention of nutritional content such as protein, crude fibre, ash, and vitamin C [11].

With time researchers found these cooking techniques adopted by rural and urban communities can affect the nutritional, polyphenolic, and quality attributes of porridge that occur during cooking [12]. A study reported that bioactive compounds such as flavonoids and phenolics reduce as the temperature and pressure increase. Similarly, another study also reported that pressure cooking directly impacts amino acid composition, protein denaturation, and carbohydrate content [13]. Therefore, it is important to select optimized cooking conditions and parameters that can be taken into account in our study for the retention of nutritional components and high antioxidant scavenging properties during preparation of porridge.

In this study, we selected uncooked samples (control), conventional, electric cooker, microwave oven, and machine-cooked methods to cook pearl millet flour porridge. However, research on pearl millet flour is limited and lacks scientific research evidence. The functional properties of flour were observed to understand its interaction with water and other ingredients that affect the physiochemical, textural, and quality of porridge during cooking. The nutritional, polyphenolic, and microbial loads of porridge were analyzed and were taken as the main evaluation objectives for this study. The microbial analysis was added to understand the product quality attributes. This study can fill the gap in the scientific research literature by examining and determining different cooking techniques and conditions on the nutritional and polyphenol assessment during processing and preparation of porridge.

## 2. Materials and Methods

### 2.1 Procurement of Raw Materials and Chemicals

Peral Millet grains were procured from the local market of Thanjavur city, India. Grains were cleaned manually to remove foreign particles and were de-husked in the laboratory using an abrasive emerge roll polisher (Model: TM 05, Satake Corporation, Japan). The de-husked millet grains were cleaned by the air winnowing method for the removal of the husk before being pulverized into flour. These grains were pulverized using Pulverize (Model ZOZ Star) and were sieved using a tabletop motorized sieve shaker machine with (BSS 410/69) to obtain fine particles and stored in zip lock packets at room temperature for preparation of sample and future analysis. The chemicals and reagents used for experiments were of high-grade Himedia brand and purchased from Suresh Scientific Pvt. ltd from, Tiruchirappalli, India.

### 2.2 Functional Properties of Peral Millet Flour

The functional properties of Peral millet flour were studied to understand its behavior during cooking. The functional properties such as bulk density (g/ml), and tapped density (g/ml) of flour were measured using the procedure mentioned by [14]. In this method, flour was filled up to 100 ml of measuring cylinder. The weight and volume of flour were noted to calculate the bulk density (g/ml). Afterward, the measuring cylinder was tapped 10 times on a surface till the particles settled in the cylinder, finally, volume was measured (g/ml) to calculate Tapped Density using equations (1) and (2).

$$\text{Bulk Density} = \frac{\text{Weight of sample (g)}}{\text{Volume of unsettled particles in measuring cylinder (ml)}} \quad (1)$$

$$\text{Tapped Density} = \frac{\text{Weight of sample (g)}}{\text{Volume of settled particles in measuring cylinder (ml)}} \quad (2)$$

The Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) of flour were studied according to the procedure mentioned in previous studies [15] with minor modifications. In this method, 1 gm of millet flour was precisely measured and added to 50ml of centrifuge tube containing 10 ml of refined oil and distilled water. The content was mixed thoroughly for 30 seconds and let it stand at room temperature for 30 mins followed by centrifuge at 2000 rpm for 30 min. Remove the supernatant and weight the tube with residue. The OAC and WAC were calculated from the increase of 1 g of sample and expressed by a gram of absorbed water and oil by the gram (db) of the sample.

Solubility (%), Swelling Power (g/g), and Dispersibility (%) of flour were examined using [16, 17]. In this method, 1 g of flour and 10 ml of distilled water slurry were heated with continuous stirring in the water bath at 90 °C for 1 hour. The Slurry was cooled at room temperature and centrifuged for 15 minutes at 4000 rpm. The supernatant and sediment were collected in a pre-weight dry petri plate and dried at 100 °C for 20 min. The weight of dry supernatant and sediment was noted to calculate Solubility (S%) and Swelling power (g/g) from Equations (3) and (4) given below.

$$\text{Solubility (\%)} = \frac{\text{Weight of dry Supernatant weight}}{\text{Initial weight of Sample}} \times 100 \quad (3)$$

$$\text{Swelling Power} \left(\frac{g}{g}\right) = \frac{\text{Weight of sediment}}{\text{Initial Weight of the Sample}} \quad (4)$$

Millet flour's Dispersibility (%) was calculated using [18]. In this method, 10 gm of sample and 100 volume distilled water was added to 100ml of measuring cylinder. Stir and allow the particles to settle for 3 hours. The volume of steeled particles was recorded and dispersibility was calculated using Equation (5) given below.

$$\text{Dispersibility}\ (\%) = 100 - \text{Volume of settled particles} \quad (5)$$

### 2.3 Sample Preparation
In this study, the porridge samples were prepared using conventional, pressure, microwave and machine for cooking porridge samples according to the procedure mentioned by [19] with some modifications. The uncooked Peral millet flour porridge sample was used as a control. In the conventional method, 50 g of Peral Millet flour was first mixed with 50 ml of normal water to form a slurry. This slurry was poured into a container containing 200 ml of boiling water and placed on the LPG stove at 100 °C with constant stirring for 15 minutes. Usha 700-Watt Automated Electric Rice cooker was used for cooking where 50 g of flour sample was added to the cooker vessel with 250 ml of boiling water and stirred initially to form a smooth slurry at 100 °C for 20 min. For microwave oven cooking, beaker was placed in a BPL-Sanyo Commercial Microwave Oven for 6min with a rotating glass table at a frequency of 2.45 GHz to avoid overcooking [20]. The machine-cooked porridge was cooked at 15 psi at 100 °C for 15 min using an automated stirring mechanism at 70 rpm.

### 2.4 Proximate Analysis
The proximate analysis of cooked porridge was calculated using the Association of Official Analytical Chemists (AOAC), and [21, 22]. The Moisture Content (MC %) (Hot air oven method), crude protein using (Kjeldahl, Pelican Kelplus, model-classic DX VA, India) apparatus, crude fiber were calculated using the acid-base method, Soxhlet technique was used to extract crude fat using N-hexane and Soxhlet apparatus of (Pelican of Soesplus, SCS06AS model and ash content was calculated using muffle furnace (Lab Field Agro and Services Pvt. Ltd, model TP-96) at 650 °C for 6 hours. Carbohydrates and Energy were Calculated using Equation (7) and (8).

$$\text{Carbohydrate}\ (\%) = 100\% - (\text{MC} + \text{Protein} + \text{Fat} + \text{Crude Fiber} + \text{Ash})\% \quad (7)$$

$$\text{Energy}\ \left(\frac{\text{Kcal}}{100\ \text{g}}\right) = (\%\ \text{Carbohydrate} + \%\ \text{Protein})4 + (\%\ \text{Fat}\ \times 9) \quad (8)$$

### 2.5 Determination of Total Phenolic, Flavonoid Content, and DPPH Radical Scavenging Antioxidant Activity
Total Phenolic, flavonoid content and DPPH radical scavenging antioxidant activity of porridge samples were determined from the extraction of samples followed by the maceration method. In this method, 5 g of sample was mixed with 50 ml of methanol in a centrifuge tube. Place the tubes on a rocking shaker (Tarson Rockymax) for 24 hours then centrifuge the filter, and collect the extracted solution in the Eppendorf tubes for future analysis.

The phenolic, flavonoid content and antioxidant activity of cooked porridge were performed according to the procedure given in [23]. The absorbance for phenolic was observed at 725 nm and measured against a blank using a spectrophotometer (UV-1800, Shimadzu Corporation Japan). The findings were presented as gallic acid equivalents. For flavonoids, the absorbance was read at 510 nm and present as the rutin equivalents (mg/g) and was expressed in terms of milligrams of rutin equivalents per gram of extract. The effect of cooking on the antioxidant activity of cooked porridge samples was estimated through standardized 1,1-diphenyl-2-pricrylhydrazy (DPPH) radical scavenging activity as mentioned by [24] with some minor modifications. The absorbance of the sample was measured at 517 nm using a spectrophotometer (UV-1800, Shimadzu Corporation Japan). Methanol was served as blank and solution without extract and results were expressed as percentage inhibition given in the Equation (9).

$$\%\ \text{of inhibation} = \frac{\text{Absorbance of control} - \text{Absorbance of testing sample}}{\text{Absorbance of control}} \times 100 \quad (9)$$

### 2.6 Water Activity and Microbial Analysis
The water activity of freshly cooked porridge samples was determined using an Aqualab water activity meter. Microbial analysis of all the cooked porridge samples was enumerated by the method described by [25]. This method took approximately 10 g of samples in 90 ml of sterilized water blank. Using the serial dilution method a series of $10^{-6}$ dilutions was obtained to estimate the Total Plate Count method & Yeast and Mold Count. From the diluted solution 1ml of sample was poured into petri plate and Plate Count Agar and Chloramphenicol Yeast Glucose Agar was poured and rotated clockwise and anticlockwise for uniform spreading of solution. After solidification, the plates were incubated microbial at 37 °C for 42 hours and 25 °C for Yeast and Mold growth for 120 hours and the colonies were counted and recorded as colony-forming units (CFUs/g).

### 2.7 Statistical Analysis
All the experiments were conducted thrice and data were expressed as means±standard deviation. Statistical analysis was performed on nutritional, total phenolic, flavonoid content, and DPPH radical scavenging antioxidant activity using SPSS statistical software with Duncan's multiple range tests where a p-value of 0.05 or less was considered to be statistically significant.

## 3. Results and Discussion
### 3.1 Peral Milet Flour Functional Properties
#### 3.1.1 Bulk and Tapp Density
Bulk and Tapped density of flour is an important parameter that determines the packaging requirements of products. The bulk and tapped density of pearl millet flour were (0.462±0.01 g/ml) and (0.718±0.01 g/ml) respectively as illustrated in Figure 1 (A). The findings agree with the results mentioned by (26) who reported that the bulk density of pearl millet flour was (0.520 g/cm$^3$). When compared with the previous results reported the bulk density of pearl millet flour ranges from (0.746-0.776 g/ml). The tapped density of pearl millet flour was reported by [27] lies within the range (0.65-0.76) g/ml based on specific variety and processing conditions. The observation showed a slight variation in density values compared with previously reported results due to the variety of pearl millet cultivars, milling processing, moisture, and bran content. Based on the bulk and tapped density value of PMF it can be recommended as highly suitable for the preparation of

porridge, weaning food formulations, and thicker food products [28]. The reported results of pearl millet flour with low density showed good flowability and compressibility characteristics.

#### 3.1.2 Water Absorption Capacity and Oil Absorption Capacity

The water and oil absorption capacity of flour plays an important role in porridge preparation because it can affect its functional and sensory properties. The WAC and OAC of flour were (1.973±0.13 g/g) and (1.040±0.15 g/g) respectively. The WAC is considering a critical function of protein in viscous food and viscous food formulation that requires hydration such as porridge. Similar results were also reported by [29] that the water absorption capacity of millet flour ranged from (1.50-3.25) g/g. Similar, results were reported by [30] the WAC of blended pearl millet flour, soybean, and bamboo pulp flour ranged between (2.70-2.91) g/ml. the variations were observed when compared with previously reported results due to differences in protein concentration and their interaction with water. The high-water absorption capacity of flour can be associated with the high starch content and protein's hydrophilic and hydrophobic nature; therefore, it can easily interact with water and enhance water uptake providing viscosity to final products. It can also be associated with the composition of carbohydrates and particle interaction with water increasing the leaching of amylose, solubility, and loss of crystalline structure [31]. Similarly, the OAC of pearl millet flour is an important functional property that can affect and facilitate the enhancement of flavour, texture, mouth feel, and porridge yield [32]. It has been attributed to the physical absorption of oil within the protein and in hydrophobic, electrostatic, and hydrogen bonds as forces that involve lipid-protein interaction. The oil absorption capacity is important for energy density and nutrients, especially for porridge prepared for infants and children.

#### 3.1.3 Solubility and Swelling Power

The study of functional parameters such as solubility and swelling power provides structural and textural consistency of flour affected during the preparation of porridge. The solubility and swelling power of pearl millet flour were (7.140±3.07%) and (8.645±0.29 g/g) respectively as shown in Figure 1 (B). In accordance with previously reported studies, it was observed the pearl millet flour swelling power lies within the range of (1.5-4 g/g) and solubility (5-15%). The variation was noticed based on previous results due to the variety, milling processing, moisture, bran and amylopectin content [33]. These parameters represent the interaction of crystalline area with amorphous and are usually influenced by amylopectin and amylose characteristics. It was observed that pearl millet has a pattern in the swelling power value less in contrast to solubility. However, there is no direct correlation between these parameters [34]. The high swelling power and solubility of pearl millet flour show good characteristics of high-quality uniform texture and improved digestibility and bioavailability of the final product.

#### 3.1.4 Dispersibility of Peral Millet Flour

Dispersibility contributes to the overall consistency, texture, and quality attributes of the final processed product. Figure 1 (C) shows dispersibility value of pearl millet flour exhibits is 71±1%. The obtained results were similar to the study reported by [35] that the dispersibility of raw millet flour ranged from 67-80%. The flour showed high dispersibility which states it can contribute to even mixing, hydration, and high quality of porridge [36]. It is the ability of flour to absorb water without forming lumps in porridge samples, with simultaneous disintegration of agglomerates, and also indicates the reconstructive ability of flour [37]. The higher value of the pearl millet flour shows that flour can better reconstitute in water and gives fine texture on mixing.

### 3.2 Crude Composition of Cooked Porridge Samples

The proximate composition of uncooked and cooked pearl millet flour porridge samples is presented in Table 1. It is clear from the table that uncooked porridge samples exhibit a higher proportion of crude nutritional composition than cooked porridge. There was a significant difference in nutrient content between these porridge samples ($p<0.05$). The moisture content of the conventionally cooked porridge sample was high when compared with machine, microwave, and pressure-cooked samples. Although these results were in agreement previously study with reported by [20] that uncooked sample exhibits MC% for uncooked, conventional, and microwave at 600 W cooked porridge sample (42.72±0.29, 88.22±0.30, 84.15±0.49) %. The loss of moisture content is attributed to evaporation losses and higher temperatures associated with different cooking techniques. Moisture content affects appearance and consistency and reduces the microbial load and spoilage [38].

Table 1 further shows machine, pressure, and microwave-cooked porridge samples exhibit high fat and protein content. Similar results were reported by [3] reduction of nutritional composition was observed for cooked porridge samples when subjected to different cooking methods. Uncooked porridge samples exhibit significantly high crude fat and protein content when compared with cooked slurry. In an uncooked sample, slurry consists of an intact structure without extraction and breakdown of fat and protein that breaks with heating when subjected to different cooking methods. The reduction of crude protein content with conventional cooking is attributed to higher temperatures that led to the denaturation of protein and functional structure losses. While in machine and pressure, cooking involves controlled cooking conditions that prevent excess nutritional breakdown and loss [39].

The fat content of machine, pressure, and microwave-cooked porridge samples was higher than conventional cooking due to the complete decomposition and breakdown of bonds that bind fatty acids together. During cooking, at high temperatures the fatty acids detach and open up leading to a rise in the fat content of the cooked porridge slurry matrix [40]. Similarly, conventionally cooked porridge samples exhibit low ash content and it increases with other cooking methods. Since the ash content depends on the dry matter of slurry it didn’t show much significant difference ($p>0.05$) in the cooked and uncooked samples, therefore it can be concluded that cooking methods don’t affect the mineral content of porridge sample.

The crude fiber content was significantly different for cooked and uncooked porridge sample. Microwave cooked porridge sample showed fiber content of (3.109±0.05%) followed by pressure (2.707±0.20%) and machine (1.200±0.21%) cooked porridge samples. Usually, the fibers of grains or plants consist of soluble fibres that dissolve in the solid and water matrix and hemicellulose, ligning and cellulose don't dissolve in the matrix and also not altered by cooking till some extent. The observed changes in crude fibre content are due to breakdown of large polymers into more soluble forms when exposed to high temperature and prolong cooking time [41]. The carbohydrate, and energy were high for the uncooked sample as illustrated in Table 1. However, the carbohydrate and energy content were reduced with cooking and the results agree with the work carried out by [42]. The significant loss of carbohydrates is attributed to the hydrolysis of carbohydrates with the formation of monosaccharides and disaccharides that are soluble and leached into the cooked sample matrix.

### 3.3 Polyphenolic Content and Antioxidant Activity of Peral Millet Flour Porridge Samples

The total phenolic, flavonoid content, and DPPH scavenging antioxidant activity of uncooked, conventional, pressure, microwave, and machine-cooked porridge samples showed a significant difference ($p<0.05$) as illustrated in Table 1. Among the porridge samples, uncooked (control) showed a higher percentage of TPC (105.059±4.11 mg GAE/100 g), TFC (83.730±3.63 mg RE/100 g) and DPPH scavenging activity of (84.051±0.63%) respectively. The uncooked porridge samples retain their natural phenolic compounds since it's not subjected to heating and processing conditions. The flour slurry subjected to open boiling and steaming processing showed a low TPC content of (15.492±1.57 mg GAE/100 g) respectively. In accordance with the previously reported study by [43] phenolic content, flavonoids, and antioxidant scavenging activity decreased when finger millet grains were subjected to open boiling. In conventional cooking, the high temperature and prolonged cooking time lead to polyphenolic content degradation, oxidation and leaching into the matrix. In agreement with the present study, it was observed that pressure-cooked porridge samples exhibit low TPC (8.667±5.88 mg GAE/100 g), flavonoids (5.158±3.63 mg RE/100 g), and antioxidant activity of (18.131±0.75%). [44] reported that the TPC and TFC of millet flour decrease during different processing such as pressure cooking and open boiling. The TFC is reduced due to the oxidation of phenolics in the presence of thermal degradation and depolymerization of phenolics with high molecular weight. However, [45] reported that based on heat treatment and cooking methods the polyphenolic content of processed food products reduces and increases.

The results in the present study showed that the polyphenolic content and radical scavenging activity of machine and microwave-cooked porridge samples were high as shown in Table 1. In this cooking method, the slurry was exposed to low heat under controlled conditions with minimum oxidation and leeching of water-soluble bioactive compounds into the medium due to the stirring mechanism and rotating plate. It also enhances the complete breakdown of granules allowing extraction and availability of polyphenolic and flavonoid content into the cooked slurry.

### 3.4 Water Activity and Microbial Colonies Load of Porridge Samples

Table 2 illustrates the results of freshly cooked pearl millet flour porridge exhibiting high water activity generally lying between (0.884±0.02 and 0.996±0.04) respectively. This range is suitable for the propagation of a wide range of microbes. The values showed a non-significantly difference ($p>0.05$) for freshly prepared of 0.996±0.04 > 0.980±0.03 > 0.979±0.09 > 0.974±0.02 > 0.884±0.02 for conventional, pressure, microwave, machine-cooked porridge, and uncooked porridge sample. The high-water activity value of porridge samples measures free water in the samples that lead to the inhibition of various microorganisms that affect the quality and shelf life [46]. Therefore, drying and preparing instant powder is the best method to preserve the quality and enhance the shelf life of this processed product for a longer period [47].

The freshly cooked pearl millet flour porridge samples were analysed for total bacterial, yeast, and mold count to ensure its safe for consumption. Table 2 characterizes the data obtained for the microbial count of uncooked, conventional, pressure, microwave, and machined cooked porridge. It was observed that bacterial yeast and mold load were high for the CCPMFP ($2.9\times10^2$ CFU/g) and ($1.010\times10^2$ CFU/g) respectively. No bacterial, yeast, and mold load was observed for pressure, microwave, and machine-cooked porridge samples. It was observed that the bacterial and yeast and mold count results meet the satisfaction levels for all freshly cooked porridge samples and yeast and mold load were less when compared with bacterial load. A similar study was conducted by [41] to observe microbial contamination in fermented cereal porridge prepared using maize and sorghum. It was found that the total viable aerobic bacterial count was ($4.6\times10^4$ CFU/ml) and ($7.3\times10^4$ CFU/ml) for maize and sorghum porridge samples at 0hr, while yeast and mold loads were ($2.9\times10^2$ CFU/ml) and ($5.2\times10^2$ CFU/ml). Another study was conducted by (49) to enumerate the microbial attributes of porridge prepared from African yam beans and corn flour blend. Based on quality assessment it was observed that bacterial load ($1.2\times10^1$ CFU/g and $1.2\times10^2$ CFU/g) and yeast and mold count lie within the acceptable International Commission on Microbiological Specification of food limits. Other organisms such as *Staphylococcus*, *Pencillum* spp. *Bacillus cereus* and *Micrococus* spp were also detected in the porridge sample. The microwave-cooked porridge samples exhibit low total bacterial and yeast, and Mold loads of ($1.4\times10^2$ CFU/g) and ($1.1\times10^2$ CFU/g) respectively. In microwave ovens electromagnetic waves penetrate slurry and create molecular movement that generates heat. However, this process usually does not ensure uniform heating which may lead to cold spots and uneven cooking affecting the quality and enhancing the inhibition of bacteria such as E. *coli, listeria, and salmonella* [50].

These results can be correlated with the moisture content and water activity of cooked porridge samples. Uncooked porridge samples exhibit high bacterial, yeast, and Mold counts before cooking due to the inhibition of natural microbial flora in grains and during the pulverization into flour [51]. It was noticed that the MC% and water activity of CCPMFP were high (86.473±0.33%) and (0.996±0.0) contributing to high water activity and moisture content indicating a higher limit of available water for microbial proliferation. Pressure and machine-cooked porridge samples have no inhibition of microorganisms due to high-temperature treatment, a closed environment, and an automated stirring mechanism that prevents cold, hot spots with uniform heating that provides high-quality cooking millet flour porridge.

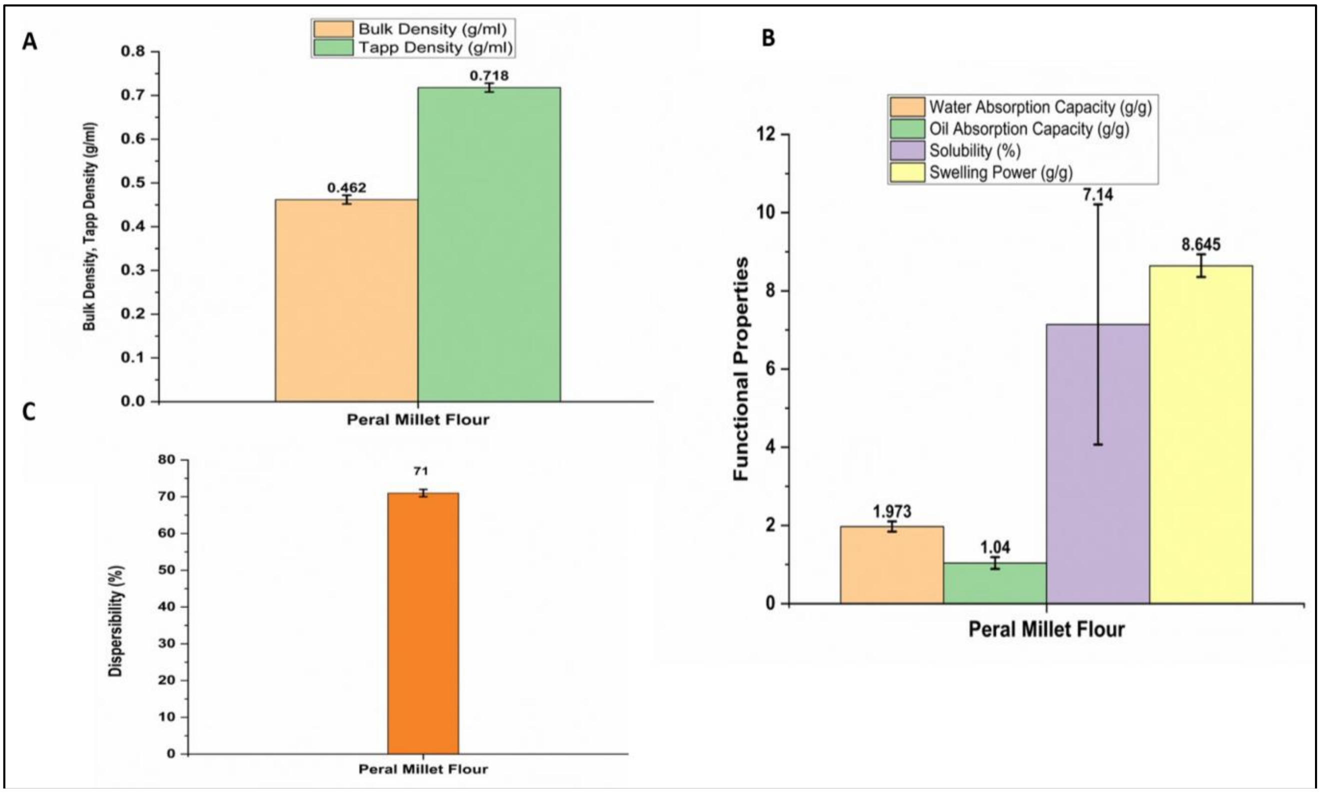


**Fig 1:** Functional Properties of Peral Millet Flour

**Table 1:** Nutritional, Polyphenolic Content, and Antioxidant Scavenging Activity of Peral Millet Flour Samples

| Parameters | Fresh Cooked Porridge Sample | | | | |
|---|---|---|---|---|---|
| | **UCPMFP** | **CCPMFP** | **PCPMFP** | **MWCPMFP** | **MCPMFP** |
| MC (%) | 63.235±0.13[e] | 86.473±0.33[a] | 71.184±0.09[d] | 83.157±0.06[b] | 78.489±0.22[c] |
| Fat (%) | 3.662±0.21[c] | 0.975±0.08[e] | 5.911±0.07[a] | 2.367±0.04[d] | 5.498±0.14[b] |
| Ash (%) | 3.059±0.02[a] | 1.266±0.02[e] | 1.689±0.05[d] | 2.551±0.03[b] | 2.070±0.02[c] |
| Crude Fiber (%) | 4.833±0.10[a] | 1.277±0.06[d] | 2.707±0.20[c] | 3.109±0.05[b] | 1.200±0.21[d] |
| Protein (%) | 8.523±0.15[a] | 4.266±0.06[d] | 5.488±0.33[b] | 4.526±0.18[d] | 5.085±0.04[c] |
| Carbohydrate (%) | 16.685±0.33[a] | 5.741±0.36[d] | 13.019±0.50[b] | 4.288±0.29[e] | 7.656±0.50[c] |
| Energy (Kcal/100 g) | 133.800±1.14[a] | 48.810±1.36[e] | 127.228±1.21[b] | 56.567±0.38[d] | 100.447±1.07[c] |
| TPC (mg GAE/100 g) | 105.059±4.11[a] | 15.492±1.57[d] | 8.667±5.88[d] | 48.562±5.88[c] | 70.807±2.97[b] |
| TFC (mg RE/100 g) | 83.730±3.63[a] | 14.682±4.95[d] | 5.158±3.63[e] | 29.761±2.38[c] | 58.412±2.38[b] |
| Antioxidant activity (%) | 84.051±0.63[a] | 26.478±1.03[d] | 18.131±0.75[e] | 60.917±1.74[c] | 75.677±0.49[b] |

**Note:** ***Values are the mean of triplicate determination (n=3)±standard deviation. Statistically significant at $p<0.05$ where a> b> c>d>e in each column. UCPMFP: Un cooked Pearl Millet Flour Porridge, CCFMFP: Conventionally cooked Pearl Millet Flour Porridge and PCFMFP: Pressure Cooked Pearl Millet Flour Porridge, MWCFMFP: Microwave Cooked Pearl Millet Flour Porridge, MCPMFP: Machine-Cooked Pearl Millet Flour Porridge, TPC: Total Phenolic Content, TFC: Total Flavonoid Content, GAE: Gallic acid equivalent, RE: Rutin Equivalent

**Table 2:** Microbial Analysis of Freshly Cooked Peral Millet Flour Porridge Samples

| Sample Name | aW | TPC (CFU/g) | Y&MC (CFU/g) |
|---|---|---|---|
| UCPMFP | 0.884±0.02[d] | 3.3×10$^2$ | 3.1×10$^2$ |
| CCPMFP | 0.996±0.04[a] | 2.9×10$^2$ | 1.0×10$^2$ |
| PCPMFP | 0.980±0.03[b] | ND | ND |
| MWPFMFP | 0.979±0.09[bc] | 1.4×10$^2$ | 1.1×10$^2$ |
| MCPMFP | 0.974±0.02[c] | ND | ND |

**Note: TPC:** aW: Water activity, Total Plate Count, Y & MC: Yeast & Mold Count, UCPMFP: Un cooked Pearl Millet Flour Porridge, CCFMFP: Conventionally cooked Pearl Millet Flour Porridge and PCFMFP: Pressure Cooked Pearl Millet Flour Porridge, MWCFMFP: Microwave Cooked Pearl Millet Flour Porridge, MCPMFP: Machine-Cooked Pearl Millet Flour Porridge, ND: Not detected

## 4. Conclusion

In this study uncooked, conventional, pressure, microwave, and machine-cooking methods were selected for the preparation of pearl millet flour porridge. The slurry was separately prepared and its nutritional composition, polyphenolic content, antioxidant properties, and quality were determined. The results indicate that pearl millet flour exhibits good functional properties such as bulk and tapped density making it a highly versatile grain for the preparation of porridge, weaning food formulations, and thicker food products. It also showed high swelling power and solubility showing good characteristics for the production of high-quality porridge with uniform texture and improved digestibility and bioavailability on consumption. The porridge cooked under machine, pressure, and microwave oven appeared less watery and had low moisture content compared with conventionally cooked porridge sample. The results indicate that cooking slurry using conventional methods at high temperatures with uncontrolled cooking conditions induced nutrition denaturation and losses that led to the reduction of amino acids, protein, and essential minerals from porridge samples. The slurry cooked in a machine and microwave oven consists of high polyphenolic content and antioxidant radical scavenging activity. The variations of nutritional, polyphenolic, and quality characteristics of these cooking conditions are attributed to the open environment, stirring mechanism, leeching of nutrients, water usage, temperature, and time. The slurry cooked in electric cookers and machine showed no inhibition of microorganisms due to high-temperature treatment, stirring mechanism that prevents from cold and hot spots with uniform heating. The results obtained from optimized cooking methods recommended that machine and microwave cooking techniques are ideal for porridge preparation to enhance nutritional properties, bioavailability, and overall acceptability for consumption.

## 5. Credit Author Statement
Sushmita Mandal-Methodology; Investigation; Research work: Data interpretation; Writing the original draft; Editing. Suresh Kumar Kalakandan-Project administration; Conceptualization; Visualization; Supervision; Provide resources, Approved for the final manuscript. V. Hema., V. Eyarkai Nambi, M. Tito Anand-Reviewed and Visualization. Suman Thamburaj-Methodology; Review and Editing.

## 6. Declaration of Interest
The authors declare no conflict of interest.

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