International Journal of Social Science Research and Review

http://ijssrr.com
editor@ijssrr.com
Volume 9, Issue 7
July, 2026
Pages: 398-417

Traditional Grinding Technology in Sri Lanka: The Domestic Rotary Quern (*Kurahan Gala*)

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http://dx.doi.org/10.47814/ijssrr.v9i7.3503

Abstract

Kurakkan (finger millet) is the second staple food in Sri Lanka and closely associated with the *Kurahan Gala* (traditional rotary quern-stone), widely used in rural dry-zone areas. This study investigated the traditional technology, physical and mechanical properties of the raw materials, grinding mechanism, and functional properties of flour milled by the *Kurahan Gala*. Field data were collected from villages of Sigiriya and Kalundewa in the Matale district, Central Province, and Oththappuwa in the Anuradhapura district, North Central Province. The design of *Kurahan Gala* has a specific materials culture consisting of two fitted granites with high durability, namely, *Yati Gala* (base stone) and *Matu Gala* (upper stones). The *Yati Gala* is larger than the *Matu Gala* for higher efficiency, acting as a primary support structure. The *Matu Gala* slightly convex on the underside, having two diametrically opposite-situated winged projections to increase the milling efficiency and a central depression to pour the grains. Durable hardwood, *Kithul*, is used to design the central alignment pin and the vertical handle due to their strength, hardness, and water resistance. Rural women are most familiar with the milling process of *Kurahan Gala* and grinding performance is dependent on the rotation speed and handling behavior. Grinding method also gets various particle sizes which fine particles has higher bulk density and greater water absorption capacity, indicating better functional properties and used for various meals based on their traditional recipes. This study demonstrated a significant relationship between the traditional grinding technology, mechanisms, usage of specified raw materials for domestic design, and the scientific knowledge of the *Kurahan Gala*.

Keywords: *Ancient technology; Kurahan Gala; Materials culture; Traditional knowledge*

1. Introduction

Kurakkan (finger millet) is a cereal crop consumed by millions of people as the second staple food after rice in Sri Lanka as well as in more than 25 countries in Africa and South Asia. *Kurakkan* are small spherical seeds, commonly deep reddish-brown to dark brown in color, that look like mustard seeds. In Sri Lanka, *Kurakkan* has been cultivated since ancient times, especially in dry and arid areas, namely Anuradapura, Moneragala, Hambantoda, Kegalle, Ratnapura, Nuwara Eliya, Matale, Ampara, Badulla, and Jaffna districts (Lewis, 1848-49). Finger millet is continuously cultivated in every *Maha* season under rainfed farming systems with the onset of monsoons in October in Sri Lanka. Accordingly, *Kurakkan* seeds are broadcast or sown and then covered and do not require the use of any organic or inorganic fertilizers under rainfed conditions during the growing season. Therefore, compared to other cereal crops, *Kurakkan* has been identified as a promising crop that can be grown under adverse soil and climatic conditions, is disease-resistant, and survives in hardy and drought-prone environments with minimal human intervention and a short cultivation duration. However, sometimes finger millet farmers have been faced with the issue of cultivation being damaged by wild animals like monkeys, elephants, and birds (Hettige , 2004; Meddegoda , 2020).

Kurakkan is most closely associated with the *Kurahan Gala*, or *Kurakkan Gala* (traditional rotary quern/ stone), which is a specially designed domestic grinder used among Sri Lanka's traditional households for milling *Kurakkan*. In the food industry, grinding is a widely used unit operation, and it is the common method for processing powder. Accordingly, grinding is the method of gradual size reduction to obtain a suitable size of particles for food processing. Usually, the *Kurahan Gala* was most commonly placed in the semi-open front of the house of *Pila* (veranda) and widely used in dry and arid areas of Sigiriya, Dambulla, Kalundewa, Alakolawewa, Inamaluwa in Matale District, Nuwara kalaviya, Polonnaruwa in North Central Province, and Monaragala in Uva Province and other agricultural societies in Sri Lanka (Bell, 1883; Coomaraswamy, 1905). The design of *Kurahan Gala* has a specific materials culture. It typically consists of two fitted granite stones, the *Yati Gala* (base stone) and *Matu Gala* (upper rotating stone), with a short hardwood pin to keep the two stone parts aligned as well as a wooden handle for easy handling, and the grains were ground between the rough surfaces of the stones for proper crushing. Its operating principle was based on the mechanical friction and shear force, where the rotation of the upper stone against the base stone crushed and ground the grain into fine flour. That's why *Kurahan Gala* was presented as an ingenious example of indigenous mechanical technology developed through traditional knowledge systems in Sri Lanka (Coomaraswamy, 1905; Davy, 1821). In the traditional milling process, the harvested *Kurakkan* pod was cleaned, the crop residuals or unwanted particles were removed, and it was dried in the sun and stored under proper conditions for up to several years without reducing the quality of the grains as a prompt solution to the forthcoming food shortage. Thereafter, dried seeds were used in the milling process as per the daily requirements. According to that, *Kurakkan* flour was used for cooking lots of traditional meals, of which *Kurakkan Thalapa* was one of the main staple foods of Sri Lankans, and usually *Thalapa was* eaten with thick curries of fish known as *Wew Malu* or cereals like *Mun* (green gram), *Kollu* (curried horse gram), or another wild bean. Apart from *Kurakkan Thalapa*, *Kurakkan Roti*, *Pittu*, *Helapa* were the main dishes in Sri Lanka, *Kurakkan Kenda* (porridge) was a popular drink among the villagers (Hettige , 2004; Siriweera , 2009).

Beyond being a tool, the *Kurahan Gala* anchored domestic food sovereignty. As a staple grain, *Kurakkan* is a highly nutritious and healthy meal, having high amounts of dietary fiber, carbohydrates, proteins, vitamins, minerals, and fatty acids and being rich in calcium. Not only that, but *Kurakkan* is a low glycemic index and gluten-free grain. Hence, consumption of *Kurakkan* assures reduction of excessive blood sugar, lowering of blood lipids, good bone health, and protection against cardiovascular diseases such as diabetes and obesity, as well as gastrointestinal cancers, while maintaining sustainable health (Siriweera , 2009). Accordingly, our ancient people use the *Kurahan Gala* for the milling process for fulfilling their daily meals with their own experience as well as traditional knowledge. However, they used the *Kurahan Gala* as a unique tool without understanding its technology, mechanisms, and the specific criteria (Hettige & Kumarasingha, 2026). Considering the above facts, this study was conducted to identify the traditional technology associated with the *Kurahan Gala*, to examine the criteria used in its construction, to further analyze the physical and mechanical properties of the raw materials, mainly their selection for their durability, surface texture, hardness, and compatibility, and to evaluate the grinding methods and the functional properties of *Kurakkan* flour as well.

Fig 1. *Kurakkan* (finger millet) plant and harvested seeds (A): Mature *Kurakkan* pods; (B): Harvested *Kurakkan* seeds
Source: (Thilakarathna & Raizada, 2015)

2. Research Questions

- What are the technological mechanisms and structural design features of the *Kurahan Gala* used in traditional Sri Lankan households?
- What criteria and physical properties of raw materials are used in the creation of *Kurahan Gala*?
- How do the operational principles of the *Kurahan Gala* and its role in preserving the quality and nutritional value of flour?
- How to determine the functional properties of milled *Kurakkan* flour using the *Kurahan Gala*?

3. Research Objectives

- To identify the technological mechanisms and structural design features of the *Kurahan Gala* used in traditional Sri Lankan households.
- To examine the selection criteria and physical properties of raw materials used in constructing the *Kurahan Gala*.
- To evaluate the operational principles of the *Kurahan Gala* and its role in preserving the quality and nutritional value of flour.
- To determine the functional properties of milled *Kurakkan* flour using the *Kurahan Gala*.

4. Materials and Methods

4.1. Sample Collection

Kurahan Gala samples in different sizes (see Fig 3) were collected from traditional Sri Lankan households still practicing in selected agricultural villages historically recognized for *Kurakkan* cultivation and use of the *Kurahan Gala* in Sigiriya and Kalundewa in the Matale district, Central Province, and Oththappuwa in the Anuradhapura district, North Central Province. In addition to that, finger millet was purchased from the local market in the Divulapitiya area of Gampaha district to examine the grinding functionality during the operating conditions of the *Kurahan Gala*.

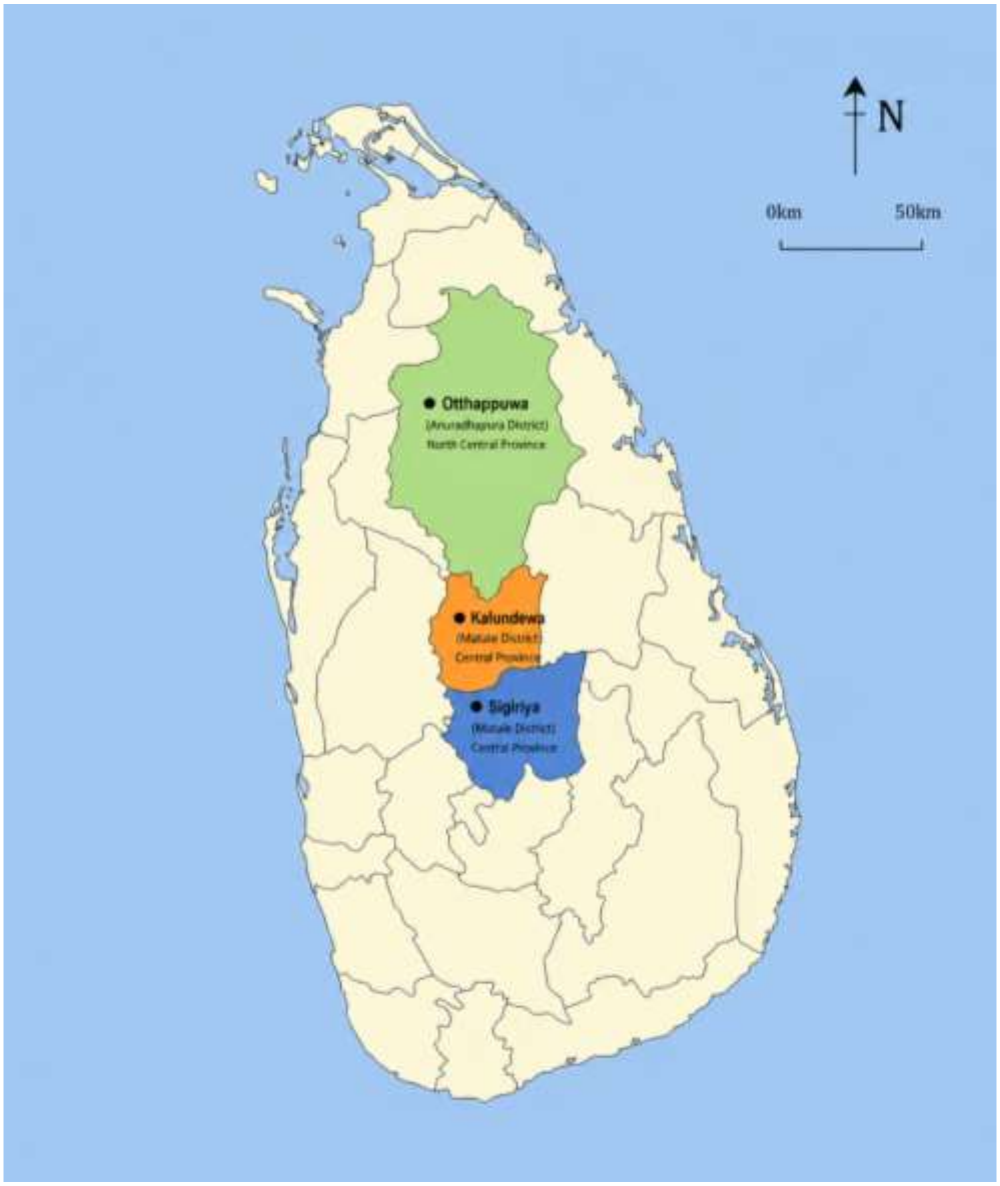


Fig 2. Different locations selected for sample collection

Table 1. Collected Samples

Sample Name	Weight of the *Yati Gala* (base stone) in kg	Weight of the *Matu Gala* (upper stone) in kg	Total Weight in kg
Sample A	26	21	47
Sample B	24	19	43
Sample C	19	14	33

Sample A: Village of Sigiriya in Matale District, Central Province	Sample B: Village of Kalundewa in Matale District, Central Province	Sample C: Village of Oththappuwa in Anuradhapura District, North Central

Fig 3. Different sizes of the *Kurahan Gala* (traditional rotary quern/ stone)

4.2. Test Equipment and Analytical Methods

All equipment and analytical methods used for this investigation were mentioned in the table below (Table 2).

Table 2. Test Equipment and Analytical Methods

Test/Method	Chemicals/Reagents	Equipment/Utensils
Determination the measurement of *Kurahan Gala*	None	Measuring tape Measuring ruler Weighting balance
Determination the rotation speed (RPM)	None	Stopwatch
Determination the particle size	None	Test sieves Sieve shaker Weight balance Brush Containers/ trays
Determination the Bulk Density (BD)	None	Measuring cylinder Weight balance Funnel Spatula Beaker
Determination the Water Absorption Capacity (WAC)	Distilled water	Centrifuge tubes Measuring cylinder Vortex mixer Centrifuge Weight balance Filter paper Beaker

4.3. Sample Preparation

After collecting each sample, two parts of *Kurahan Gala* were dry-cleaned with a soft brush to remove loose residues, and thereafter, stones were wiped with a clean cloth to remove fine dust until completely dry, and other cleaned utensils were used to avoid any contamination. As well as *Kurakkan* grains, which were cleaned by removing stones, straw, and husk fragments by manual sorting and winnowing and visually inspected for any further pests or visible damage. Also, finger millet was cleaned with clean water and sun-dried to a safe moisture content around 10-12%, preventing microbial contamination, and stored in airtight containers for further use.

4.4. Procedures of Methodology

4.4.1. Identify the Technological Mechanisms and Structural Design Features of the *Kurahan Gala*

This study employed a qualitative and technological descriptive research design to analyze the traditional technology, construction principles, and mechanisms of the *Kurahan Gala* used in traditional Sri Lankan households. Based on that, field observations and data collection were conducted in selected agricultural villages historically recognized for *Kurakkan* (finger millet) cultivation and use of the *Kurahan Gala* in Sigiriya and Kalundewa in the Matale district, Central Province, and Oththappuwa in the Anuradhapura district, North Central Province, by conducting key informant interviews with villagers and elderly household members who have long-term experience using the *Kurahan Gala*, and data were compared with literature findings.

4.4.2. Examine the Selection Criteria and Physical Properties of Raw Materials Used in Constructing the *Kurahan Gala*

On-site technological observations were made to document the structure of *Kurahan Gala*, and information was collected to finalize the raw materials used to construct the *Kurahan Gala* for each part separately. In addition to that, measurements of weight, length, width, thickness, etc., were taken for each part (see Fig 7 and 8, respectively) for further identification, and data were analyzed using descriptive and comparative analysis techniques.

4.4.3. Evaluate the Proper Grinding Method of *Kurahan Gala*

To evaluate the proper grinding method of *Kurahan Gala*, basically two methods (see Fig 4), which vary depending on how to handle the *Kurahan Gala*, were evaluated, and thereafter, the particle size of the ground flour was determined using Sample A *Kurahan Gala*. In the first method (M1), a handful of dried seeds were poured into the central depression of the *Kurahan Gala* and ground simultaneously by rotating it. In the second method (M2), the dried seeds are gradually poured into the central depression with the hand and gradually ground by rotating it in a clockwise direction, respectively. To determine the particle size distribution of finger millet flour, 100 g from each grinding method ground by Sample A *Kurahan Gala* was measured using an analytical balance, and a sieve analysis technique was done for 10 minutes with the aid of the Endecotts Test Sieve Shaker with respect to the different sieve apertures, including 425, 300, 150, 75, and 38 µm. Thereafter, the flour retained on each sieve was measured, and the mean particle size of the flour was determined according to the following formula (Bolade, 2020).

$$\text{Mean particle size (MPS)} = (W1\times d1 + W2\times d2 + W3\times d3 + W4\times d4 + W5\times d5)/T$$

Where;

W1-5 = weight of flour through each sieve

d1-5 = diameter of mesh for each sieve

T = total sample weight

see Appendix 1

Fig 4. Different grinding methods of *Kurahan Gala* (M1): A handful of dried seeds were poured into the central depression of the *Kurahan Gala* and ground simultaneously; (M2): Dried seeds are gradually poured into the central depression with the hand and gradually ground by rotating it in clockwise direction

4.4.4. Determination of the Rotational Speed of *Kurahan Gala*

To determine the grinding efficiency of the *Kurahan Gala*, Sample A *Kurahan Gala* was used, and randomly selected women were observed, and the data was recorded during the grinding process with respect to the time, and the rotational speed during the grinding process was calculated in revolutions per minute (RPM).

4.4.5. Determining the Functional Properties of Flour Ground by *Kurahan Gala*

4.4.5.1. Determination of the Bulk Density (BD)

To determine the bulk density of ground flour using *Kurahan Gala*, 1 g of the flour from each method of M1 and M2 in several grinding times was measured and added into 10 ml test tubes. Known volume and permanently tapped until there were no more changes in volume, and then the final bulk volume of the sample was recorded, and bulk density was calculated according to the given formula as follows.

$$\textit{Bulk density (g/ml)} = \frac{\textit{Weight of flour used}}{\textit{Volume of the flour after tapping}}$$

see Appendix 2, 3.

4.4.5.2. Determination of the Water Absorption Capacity (WAC)

To determine the water absorption capacity (WAC) of flour, which was ground several times using the *Kurahan Gala*, 1 g of sample was weighed and mixed with 10 ml of distilled water for 30 seconds at room temperature. Thereafter, the suspension of flour was left to stand for half an hour and then centrifuged at 5000 rpm for 20 minutes. After that, the microcentrifuge tubes were kept at an angle to remove clear water, and the tubes were weighed, and the difference in weight calculated the weights of the supernatants before and after draining the water and calculated the WAC based on the following equation (Walaa, et al., 2025).

$$\text{Water Absorption Capacity} = \frac{W3 - W2}{W1}$$

Where,

W1 = weight of a sample

W2 = weight of empty tube + sample before centrifuging before the addition of water

W3 = weight of empty tube + the sample after centrifugation and decanting

see Appendix 4, 5.

5. Results and Discussion

5.1. Technological Mechanisms and Structural Design Features of the *Kurahan Gala*

The principle of the milling process of the *Kurahan Gala* was followed by the mechanical friction and compression between two rough stone surfaces with a stationary base stone and a manually rotated upper stone (see Fig 5), producing a theoretical extraction rate of 100%. Accordingly, when *Kurakkan* seeds were fed between the stones, the applied pressure and circular motion caused shear, crushing, and abrasion and broke the grains into fine particles without generating excessive heat. In addition, in this process, the dry milling method was followed, which cleaned and sun-dried *Kurakkan* grains with safe moisture content around 10-12%, preventing microbial contamination, and fed grains into the *Kurahan Gala*. Therefore, the technology of the low-speed, cold milling process, a dry method in the *Kurahan Gala,* helped to retain the natural color, aroma, and nutrient composition of the flour as well as prevent further microbial growth and rancidity (Joinville, 1803; Ethanahami, 2004).

Fig 5. Traditional milling process using the *Kurahan Gala*

5.2. Selection Criteria and Physical Properties of Raw Materials Used in Constructing the *Kurahan Gala*

The *Kurahan Gala* was ingeniously designed with two fitted granite stones (see Fig 6) because of their high durability, efficiency, and safe food-grinding purposes. It worked together in perfect harmony as *Yati Gala* (base stone) and *Matu Gala* (upper rotating stone) with a short hardwood pin to keep the two stone parts aligned as well as a wooden handle for easy handling, and the grains were ground between the rough surfaces of the stones for proper crushing. Not only that, but the total weight and balance of the *Kurahan Gala* are designed to enhance efficiency and safety, and it is also easily operated by a single person, usually a woman seated while feeding the grains gradually as well.

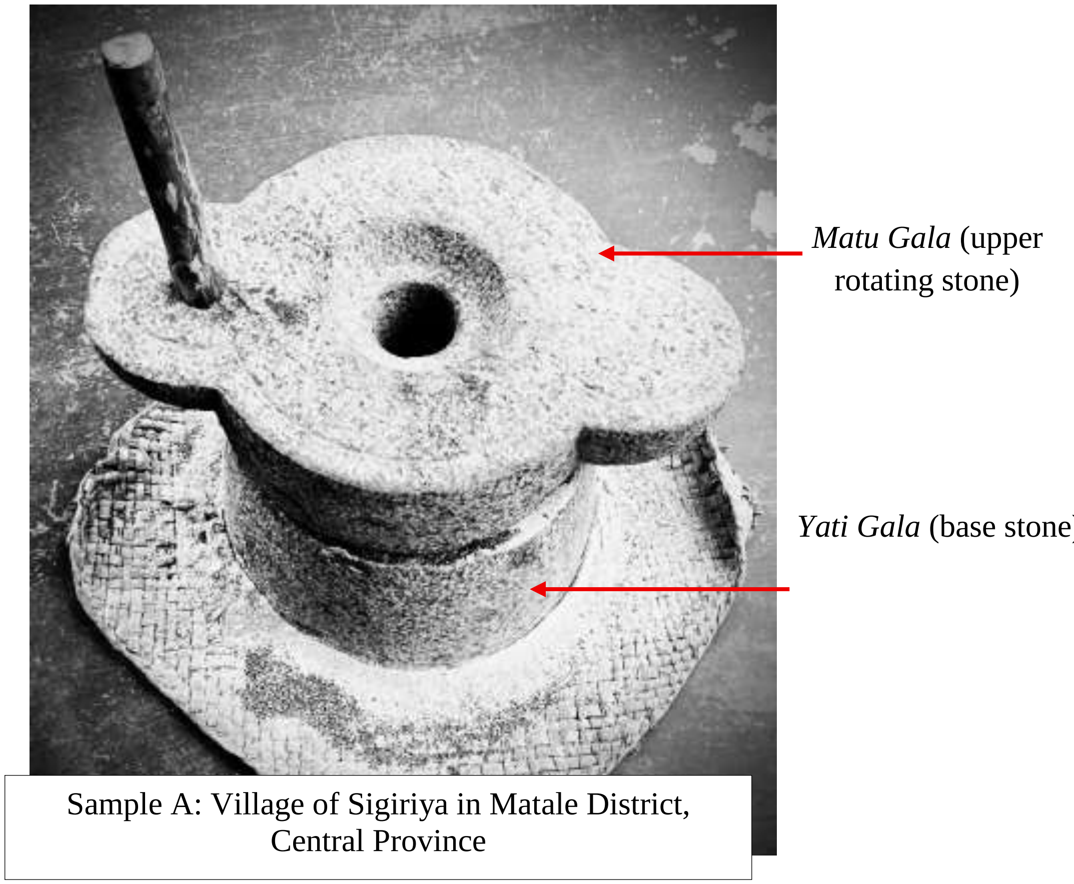
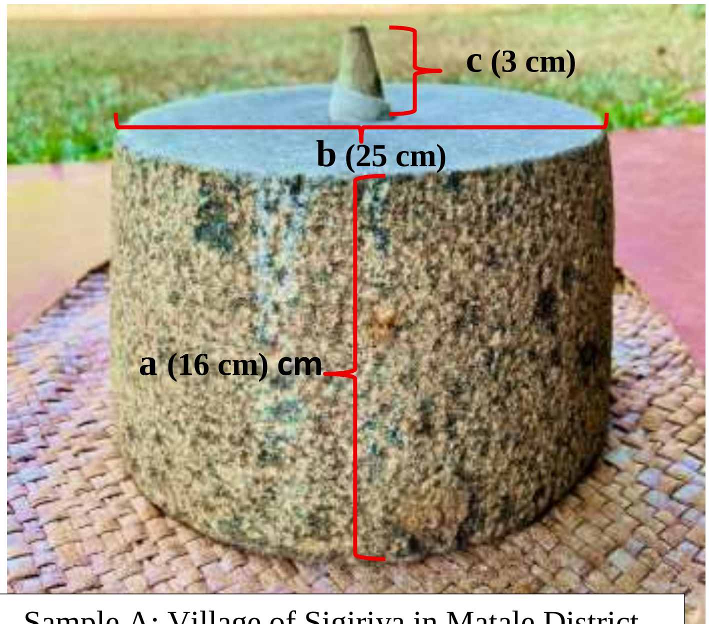


Fig 6. *Kurahan Gala* alone with *Yati Gala* (base stone) and *Matu Gala* (upper rotating stone)

- ***Yati Gala* (base stone)**

Based on the results with respect to the selected samples, the approximate height of the *Yati Gala* or base stone is 14-15 cm, and the diameter is 22-25 cm (see Fig 7). It was the foundation and primary support structure of the traditional milling system and was placed in the semi-open front of the house of *Pila* (veranda) of the traditional house. It has a short wooden pin in the center of its upper surface, fitted firmly into a central cavity in the upper stone for the rotary component as well, and the cavity has an inverted cone shape. The upper surface of the *Yati Gala* was smooth and flat for improving the grinding efficiency and quality of the flour, which ensures uniform contact between the base stone and the rotating upper stone, allowing consistent friction and pressure to be applied across the entire grinding area as well. In addition to that, the smooth surface also made it easier for the user, usually a woman, to continuously rotate the upper stone with less physical effort. Based on the measurements (Table 3), it has a cylinder shape, and the weight of the *Yati Gala* is also high, weighing more than the upper stone, above 23-25 kg, preventing movement during the grinding process and ensuring safety for the user (Somapala, 2004).



Sample A: Village of Sigiriya in Matale District, Central Province

Fig 7. *Yati Gala* (base stone) of the traditional *Kurahan Gala*

Table 3. Measurements of the *Yati Gala* (base stone) - Figure 7

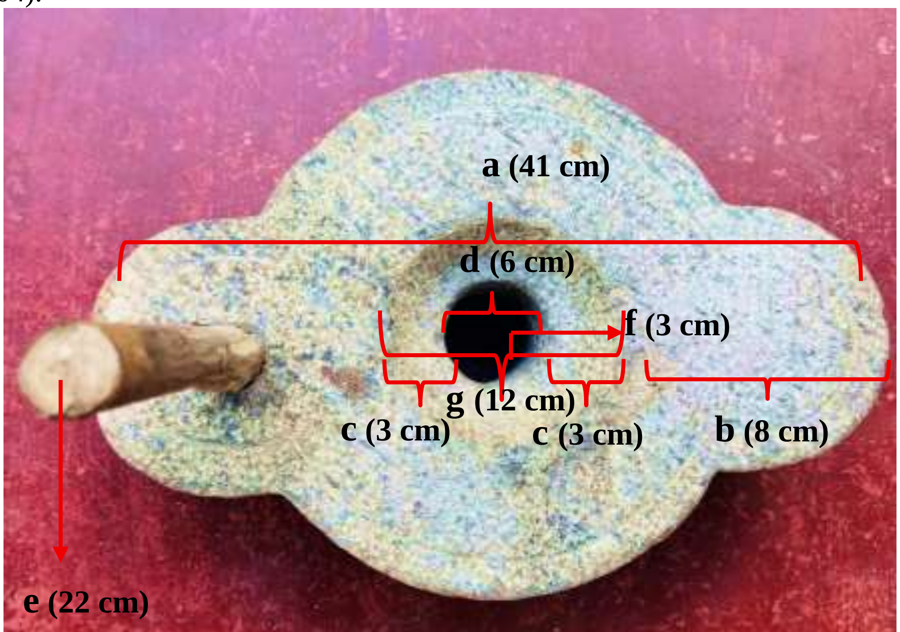
Measurements	**Sample A**	**Sample B**	**Sample C**
Length/Width (cm)			
a – Height of the *Yati Gala*	16	15	14.5
b – Diameter of the *Yati Gala*	25	23.5	22.5
c – Height of the Short Hardwood Pin	3	4	3
Weight (kg)	26	24	19

- **Short Hardwood Pin**

A short hardwood pin in the *Kurahan Gala* (see Fig 7) acts as the central alignment and rotational axis that connects the base stone with the upper rotating stone to maintain the proper alignment and balance during the grinding process while allowing smooth and controlled rotation of the upper stone. Accordingly, this pin was fixed permanently in an upright position into a depression at the center of the *Yati Gala* and passed into the corresponding depression of the upper stone to ensure consistent circular motion without creating any wobbling. Basically, this pin was traditionally made from short hardwoods above 3-5 cm in length, namely *Kithul* wood (*Caryota urens*), because of their high strength, hardness, and resistance to wear. Hence, *Kithul* wood has a fibrous natural structure, resistance to cracking and deformation, and the ability to absorb minor vibrations even under continuous rotation stress during the grinding process, and it ensures a long shelf life even in a humid environment (Janavamsa, 1886).

- ***Matu Gala* (upper rotating stone)**

The upper stone of the *Kurahan Gala* (see Fig 8), known as the *Matu Gala*, was also a cylinder shape, slightly convex on the underside, allowing it to make even contact with the flat or gently concave surface of the *Yati Gala*. It has two diametrically opposite-situated winged projections to increase the milling efficiency due to the high weight and a central depression to pour the grains and cereals, ensuring the prevention of grains dispersing. Another short stick was fixed upright to one of these projections for handling to turn the stone for the proper grinding purpose. In the grinding process, a small handful of dried grains was poured into the central depression, and thereafter, the grains were passed through the depression onto the upper surface of the lower stone when the upper stone was rotated rapidly and ground the grains between the two surfaces of the stones. More grain can be added into the depression, and the rotating action repeated until sufficient ground grain has been collected. Based on the measurements (Table 4), approximately, the weight of the upper rotating stone is also less than *Yati Gala,* above 21-22 kg, to apply the necessary grinding pressure and control it comfortably. Finally, finely ground powder fell and was collected onto the *Athulpatha* (collecting mat), which has been kept under the base stone (Somapala, 2004).



Sample A: Village of Sigiriya in Matale District, Central Province

Fig 8. *Matu Gala* (upper rotating stone of the traditional *Kurahan Gala*

Table 4. Measurements of the *Matu Gala* (upper rotating stone) - Figure 8

Measurements	Sample A	Sample B	Sample C
Length/Width (cm)			
a – Outer diameter	41	36.5	36.5
b – Diameter of the wing projection	08	6.5	7.5
c – Width of the seeds outlet channel	03	03	02
d – Central diameter	06	06	04
e – Length of the handle	22	24	21
f – Depth of the central dispersion	3	2.5	2.5
g – Diameter of the inner circle	12	12	08
Weight (kg)	21	24	19

- **Wooden Handle**

A vertical hardwood handle was anchored in the smaller hole on the side of the upper stone that enables the manual rotation of the upper stone, thus converting human effort into the circular motion needed for grinding *Kurakkan*. It was also made from *Kithul* wood due to its excellent strength and smooth texture, as well as resistance to wear and moisture. From a design perspective, the length, approximately 22–25 cm, and angle of the handle were carefully designed to fulfill the natural arm movement of the user for high efficiency without strain.

5.3. Determination of the Rotation Speed, *Kurahan Gala*

Based on the results of the rotation speed of the *Kurahan Gala* used by Sample A (Table 5), it demonstrates clear variability among individuals, which means the grinding process was inherently person-dependent, influenced by individual factors including physical strength, grinding technique, and familiarity with the traditional grinding technique. However, sometimes, two women participated in the grinding process of *Kurahan Gala* instead of individuals to enhance the efficiency.

Table 5. Results of the Rotation Speed of *Kurahan Gala*

Sample Name	Revolutions per minute (RPM)	Revolutions per second (RPS)	Radians per second (rad/s)
Person 1	52	0.87	5.47
Person 2	61	1.02	6.41
Person 3	48	0.80	5.03

5.4. Evaluate the Proper Grinding Method of the *Kurahan Gala*

Based on the results of the proper grinding method of *Kurahan Gala* with respect to Sample A, the grinding process of M2 which seeds are gradually poured into the central depression with the hand and gradually ground by rotating it in a clockwise direction, was most suitable for getting fine particles of flour for culinary purposes. Hence, with respect to the sieve analysis with apertures of 425, 300, 150, 75, and 39 µm, the M2 sample had a lower mean particle size of 188.89 µm, representing medium-sized flour, than M1, which had 346.5 µm as coarse flour (see Fig 9). It can be confirmed that these two grinding methods had significantly different particle sizes, with M2 having substantially fine particles and M1 being predominantly coarse. Nevertheless, coarse finger millet flour contains more *Kurutta* (bran/outer layer) due to the fact that during the grinding, it does not break into very fine particles, while fine flour has lower *Kurutta* and a smoother texture. According to that, in the preparation of different meals, especially coarse flour with high *Kurutta* is used for making *Kurakkan Pittu*, and fine particles are also used for making *Kurakkan Thalapa*, *Halapa*, *Roti*, etc. That is why ancient people used the *Kurahan Gala* grinding technology based on their different applications, which not only makes coarse flour rich in nutrient compounds but is also good for health benefits due to its higher *Kurutta* than fine flour.

Fig 9. Particle size distribution of finger millet flour in different grinding methods (M1): A handful of dried seeds were poured into the central depression of the *Kurahan Gala* and ground simultaneously; (M2): Dried seeds are gradually poured into the central depression with the hand and gradually ground by rotating it in clockwise direction

5.5. Determining the Functional Properties of Flour Ground by *Kurahan Gala*

5.5.1. Determination of the Bulk Density (BD)

The results of the bulk density of the ground flour, using the Sample A *Kurahan Gala*, demonstrate a consistent difference between the two grinding methods, with M2 showing higher bulk density values (approximately 0.728 ± 0.328) compared with M1. It can be highlighted that bulk density was directly associated with the smaller mean particle size observed in M2. In M1, conversely, the coarser particles produced lower bulk density, approximately 0.605 ± 0.062. Therefore, it can be concluded that, in the traditional *Kurahan Gala* grinding process, finer particles were more suitable when higher bulk density was required for good storage efficiency, proper culinary and processing applications (dough cohesiveness), and good meal texture.

Table 6. Results of Bulk Density (BD)

Sample Name	M1 (g/ml)	M2 (g/ml)
GKF-1	0.599±0.016	0.734±0.240
GKF-2	0.607±0.008	0.707±0.160
GKF-3	0.613±0.173	0.742±0.655
GKF-4	0.607±0.006	0.730±0.265
GKF-5	0.598±0.107	0.726±0.319

GKF – Ground Kurahan Flour; M1 – Method 1; M2 – Method 2

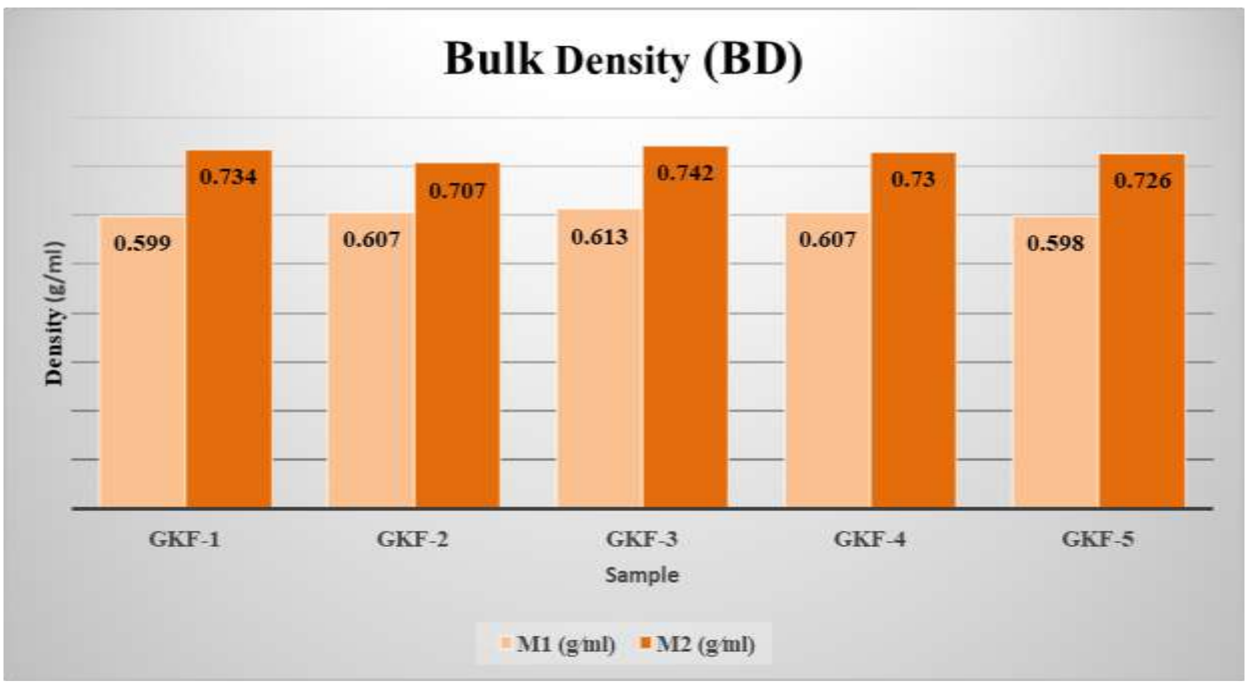


Fig 10. Bulk density differentiation of finger millet flour milled using the Sample A *Kurahan Gala*

5.5.2. Determination of the Water Absorption Capacity (WAC)

The water absorption capacity results revealed a consistent difference between the two grinding methods, with M2 recording higher WAC values (approximately 3.127 ± 0.327) than M1 (approximately 1.995 ± 0.391). Hence, the finer particle size produced by M2, which increases the surface area available for water absorption. Therefore, the traditional *Kurahan Gala* grinding approach not only preserves the traditional grinding process but also improves the functional quality of *Kurahan* flour through the production of finer particles with better water absorption properties.

Table 7. Results of Water Absorption Capacity (WAC)

Sample Name	M1	M2
GKF-1	2.017±0.386	3.053±0.586
GKF-2	1.907±0.290	2.893±0.252
GKF-3	1.963±0.153	3.157±0.351
GKF-4	2.100±0.819	3.087±0.220
GKF-5	1.989±0.306	3.443±0.224

GKF – Ground Kurahan Flour; M1 – Method 1; M2 – Method 2

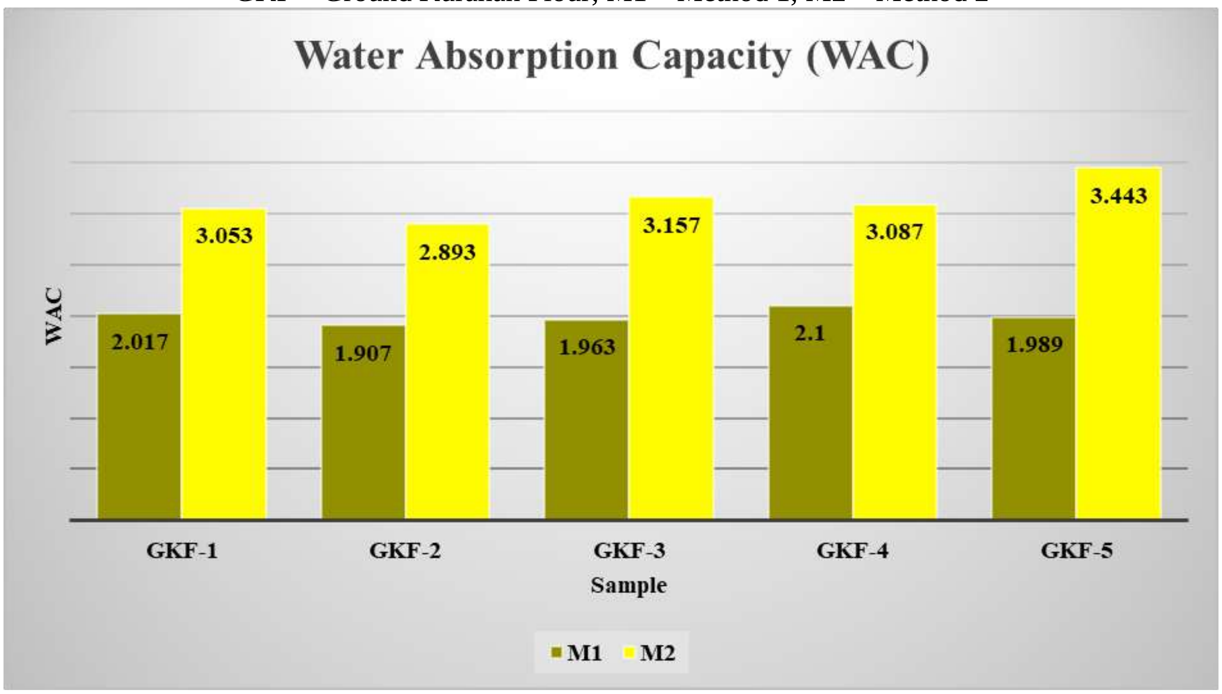


Fig 11. Water absorption capacity differentiation of finger millet flour milled using the Sample A *Kurahan Gala*

5.6. Advantages of the *Kurahan Gala* Use in Traditional Sri Lankan Households

Usage of the traditional *Kurahan Gala* offered multiple advantages in terms of food quality, household convenience, and sustainability. Accordingly, in this technology, it retains natural nutrients and flavor because low temperature avoids nutrient loss and oxidation. Nevertheless, when comparing the modern grinding mills currently available in the market, it powders most fine particles of flour, generally having smoother texture and lower fiber, while *Kurahan Gala*-based grinding flour contains medium-particle-size flour with higher dietary fiber, nice dark color, rough texture, more minerals, and other nutrient compounds. Also, dry grinding reasons to advantages in preventing microbial contamination and rancidity, reducing waste, and giving a higher flour yield from the same grain weight as well. Not only that, but usually *Kurahan Gala* was cleaned by following dry cleaning, which involved winnowing and sieving, and it helped to avoid moisture reabsorption before grinding. Also, it's easy for household use; freshly ground flour can be made for daily meals or can be stored for a long shelf life due to the lower moisture content, which further prevents microbial growth and rancidity. Nevertheless, the grinding process by using *Kurahan Gala* is also an energy-efficient and eco-friendly method due to the manual process and lack of heat or power, while reducing energy use as well as environmental impact.

5.7. Analytical Discussion

Based on the research findings of this study, we can observe that the traditional technology of *Kurahan Gala* is scientifically aligned with modern processing principles, as results of both approaches suggest that traditional knowledge has been successfully incorporated into the scientific evaluation. According to that, ancient people used the dual-stone structural design due to its high durability, efficiency, and safe food-grinding purposes. Also, *Kurahan Gala* has a unique materials culture. However, it can be scientifically proven that granite stone was used due to its high durability as well as to increase the grinding efficiency. In addition to that, *Kithul* wood was used because of its high strength, hardness, and resistance to wear. Nevertheless, properly cleaned, sun-dried seeds were used due to lower moisture content and have higher grinding efficiency as well. In ancient technology, they followed the rotating technique where the seeds fell onto the two granite stones. Accordingly, the principle of the milling process is the mechanical friction and compression between two rough stone surfaces with a stationary base stone and a manually rotated upper stone, producing a theoretical extraction rate and crushing and abrasion and breaking the grains into fine particles without generating excessive heat. Also, the rotation speed was changed by person to person based on their grinding abilities. Not only that, ancient people used *Kurakkan* flour based on their own experience but also with respect to the traditional recipes. However, the particle size of the flour varies depending on the grinding method, and especially fine flour has higher water absorption capacity and bulk density, which is easy to use in culinary applications of dough preparation, storage, etc., than coarse *Kurakkan* flour. Accordingly, coarse flour with high *Kurutta* is used for making *Kurakkan Pittu*, and fine particles are also used for making *Kurakkan Thalapa*, *Halapa*, *Roti*, etc.

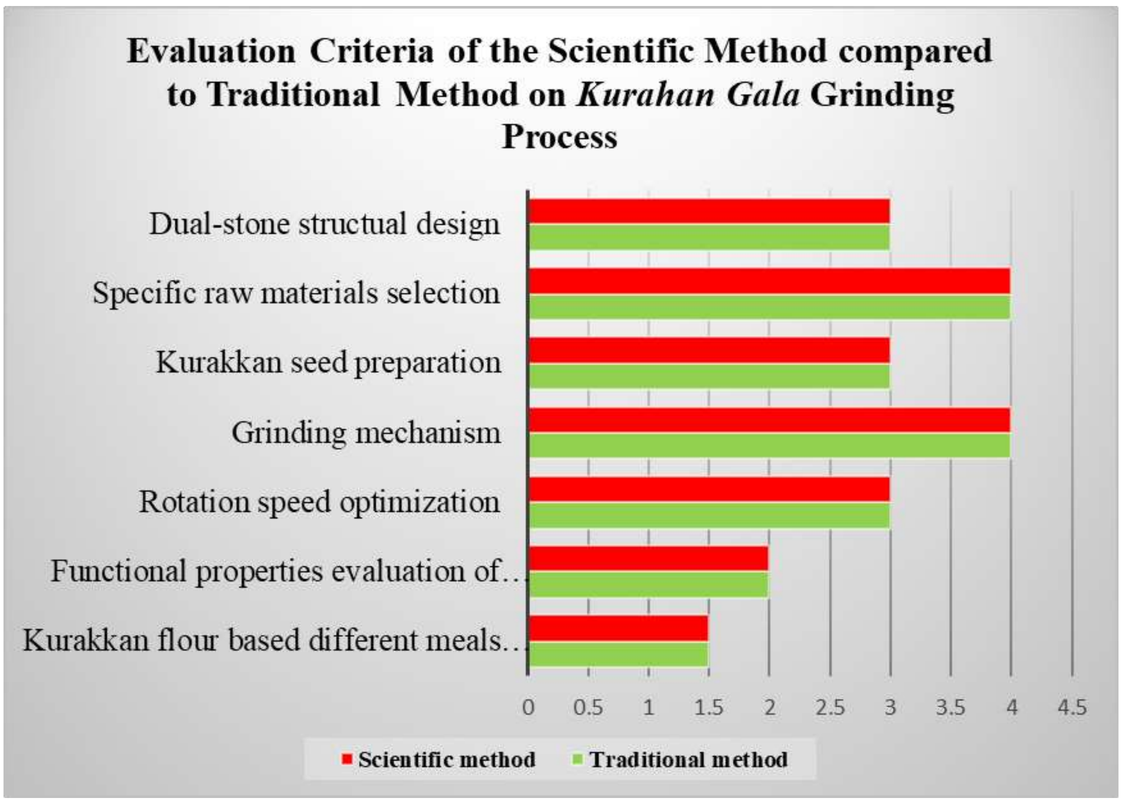


Fig 12. Evaluation criteria of the scientific method compared to traditional method on *Kurahan Gala* grinding process

6. Conclusion

Kurahan Gala, or *Kurakkan Gala*, is a specially designed domestic grinder used among Sri Lanka's traditional households in dry and arid areas of agricultural societies. Rural people designed the *Kurahan Gala* with two fitted granites, namely, the *Yati Gala* and *Matu Gala* stones, and *Yati Gala* is larger than the *Matu Gala*. Granite is used due to its high durability, efficiency, and safe food-grinding purposes. Also, the *Yati Gala* or base stone, was the foundation and primary support structure with an approximate height of 14-15 cm and a diameter of 22-25 cm. It has a cylinder shape, and the weight of the *Yati Gala* is also high, weighing more than the upper stone, above 23-25 kg, preventing movement during the grinding process and ensuring safety for the user. The upper stone of the *Kurahan Gala*, known as the *Matu Gala*, was also a cylinder shape, slightly convex on the underside, allowing it to make even contact with the flat or gently concave surface of the *Yati Gala*. It has two diametrically opposite-situated winged projections to increase the milling efficiency due to the high weight and a central depression to pour the grains and cereals, ensuring the prevention of grains dispersing. The design of *Kurahan Gala* has a specific materials culture; ancient people used specific woods to design some parts of *Kurahan Gala*. A short hardwood pin in the *Kurahan Gala* acts as the central alignment and rotational axis that connects the base stone with the upper rotating stone to maintain the proper alignment and balance during the grinding process while allowing smooth and controlled rotation of the upper stone. Basically, this pin was traditionally made from short hardwoods above 3-5 cm in length, namely *Kithul* wood, because of their high strength, hardness, and resistance to wear. Another short stick was fixed upright to one of these projections for handling to turn the stone for the proper grinding purpose. A vertical hardwood handle made from *Kithul* was anchored in the smaller hole on the side of the upper stone that enables the manual rotation of the upper stone, thus converting human effort into the circular motion needed for grinding *Kurakkan*. Usually, rural women are most familiar with the milling process of *Kurahan Gala*, and they use properly cleaned, sun-dried Kurakkan seeds based on their own knowledge. With respect to the rotation speed optimization, grinding performance was dependent on the person due to variation in rotation speed and handling behavior, and two women participated to enhance the grinding process. Furthermore, they used ground flour for various meals based on their traditional recipes with respect to the functional properties of ground flour using the *Kurahan Gala*. Even though this study suggested that the grinding method also gets various particle sizes, in which dried seeds are gradually poured into the central depression with the hand and gradually ground by rotating it in a clockwise direction, which is the best method, fine particles of finger millet powder are associated with higher bulk density (approximately 0.728 ± 0.328) and greater water absorption capacity (approximately 3.127 ± 0.327), indicating better functional properties for culinary and processing uses.

7. Statements and Declarations

7.1. Ethics Approval and Consent to Participate
Not applicable

7.2. Consent for Publication
Authors provide consent for the publication of the manuscript information.

7.3. Availability of Data and Materials
All data analyzed during this study are included in this research paper.

7.4. Competing Interests
The authors declare that they have no competing interests.

7.5. Funding Source
The study was conducted with personal commitments to research design, data collection and data analysis, and writing the manuscript for publication.

7.6. Acknowledgements
The authors wish to express sincere gratitude to the Sri Lankan villages in rural communities for generously sharing their traditional knowledge, experience, and practices, and to all individuals who contributed to the successful completion of this study.

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10. Appendixes

- **Appendix 1: Determination of Mean Particle Size of Finger millet Flour**
  - **Sieve Analysis Results of Method 1**

Fraction (µm)	Weight retained Wi (g)	Wi × di
425	51	21,675
300	39	11,700
150	07	1050
75	03	225
38	0	0

Mean particle size (MPS) of Method 01 = (W1×d1+W2×d2+W3×d3+W4×d4+W5×d5)/T
= (21,675+11,700+1050+225+0)/100
= 34,650/100
= <u>346.5 µm</u>

- **Sieve Analysis Results of Method 2**

Fraction (µm)	Weight retained Wi (g)	Wi × di
425	05	2125
300	26	7800
150	52	7800
75	14	1050
38	03	114

Mean particle size (MPS) of Method 02 = (W1×d1+W2×d2+W3×d3+W4×d4+W5×d5)/T
= (2125+7800+7800+1050+114)/100
= 18,889/100
= <u>188.89 µm</u>

- **Appendix 2: Test Results of Bulk Density in Method 1**

Replicates	Volume after tapping (ml)	Density (g/ml)
M1-1	1.72	0.581
M1-1	1.63	0.613
M1-1	1.66	0.602
M1-2	1.67	0.598
M1-2	1.63	0.613

M1-2	1.64	0.609
M1-3	1.64	0.609
M1-3	1.58	0.632
M1-3	1.67	0.598
M1-4	1.63	0.613
M1-4	1.66	0.602
M1-4	1.65	0.606
M1-5	1.64	0.609
M1-5	1.70	0.588
M1-5	1.68	0.595

M1 – Method 1

- **Appendix 3: Test Results of Bulk Density in Method 2**

Replicates	Volume after Tapping (ml)	Density
M2-1	1.32	0.757
M2-1	1.41	0.709
M2-1	1.36	0.735
M2-2	1.40	0.714
M2-2	1.39	0.719
M2-2	1.45	0.689
M2-3	1.37	0.729
M2-3	1.46	0.684
M2-3	1.23	0.813
M2-4	1.42	0.704
M2-4	1.37	0.729
M2-4	1.32	0.757
M2-5	1.38	0.724
M2-5	1.42	0.704
M2-5	1.39	0.719

M2 – Method 2

- **Appendix 4: Test Results of WAC in Method 1**

Sample Name	Water Apsorption Capacity (WAC)
M1-1	2.34
M1-1	2.12
M1-1	1.59
M1-2	1.58
M1-2	2.13
M1-2	2.01
M1-3	1.95
M1-3	1.98
M1-3	1.96
M1-4	2.12
M1-4	2.17
M1-4	2.01
M1-5	1.98
M1-5	1.96
M1-5	1.92

M1 – Method 1

- **Appendix 5: Test Results of WAC in Method 2**

Sample Name	Water Absorption Capacity (WAC)
M2-1	3.01
M2-1	3.03
M2-1	3.12
M2-2	2.87
M2-2	2.89
M2-2	2.92
M2-3	3.12
M2-3	3.16
M2-3	3.19
M2-4	2.98
M2-4	2.94
M2-4	3.34
M2-5	3.21
M2-5	3.67
M2-5	3.45

M2 – Method 2