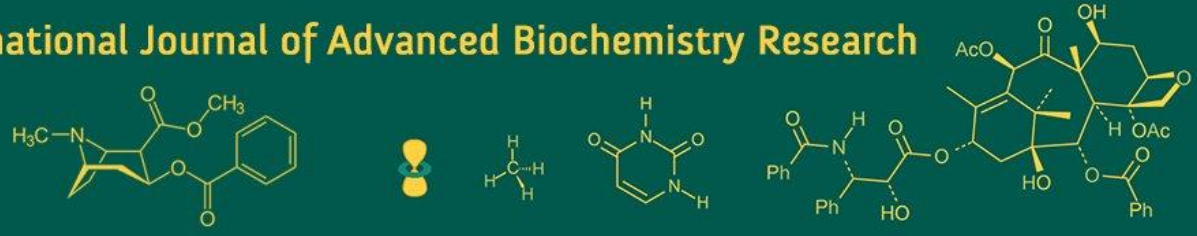
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(6): 81-87
www.biochemjournal.com
Received: 02-03-2025
Accepted: 06-04-2025

Vinass Jamali Pitchai Mydeen
Department of Food Plant Operations, Incubation and Entrepreneurship, National Institute of Food Technology Entrepreneurship and Management, Thanjavur, Tamil Nadu, India

Eyarkai Nambi Vijayaram
Department of Food Plant Operations, Incubation and Entrepreneurship, National Institute of Food Technology Entrepreneurship and Management, Thanjavur, Tamil Nadu, India

Loganathan Manickam
Department of Food Packaging and Storage Technology, National Institute of Food Technology Entrepreneurship and Management, Thanjavur, Tamil Nadu, India

Shanmugasundaram Saravanan
Department of Food Plant Operations, Incubation and Entrepreneurship, National Institute of Food Technology Entrepreneurship and Management, Thanjavur, Tamil Nadu, India

Chandrasekar Veerapandian
Department of Food Process Technology, National Institute of Food Technology Entrepreneurship and Management, Thanjavur, Tamil Nadu, India

Corresponding Author:
Eyarkai Nambi Vijayaram
Department of Food Plant Operations, Incubation and Entrepreneurship, National Institute of Food Technology Entrepreneurship and Management, Thanjavur, Tamil Nadu, India

Characterization of physical and engineering attributes of Thanjavur Ponni rice and the study of their interrelationships for quality evaluation of the rice grains

Vinass Jamali Pitchai Mydeen, Eyarkai Nambi Vijayaram, Loganathan Manickam, Shanmugasundaram Saravanan and Chandrasekar Veerapandian

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i6b.4504

Abstract
The physical characteristics of rice grains play a crucial role in determining quality, forecasting storage behavior, and enhancing the design of processing equipment and to develop storage structures that involves in the long-term storage of grains with reduced storage loss. These traits are especially important when assessing long-term stored grains affected by insect infestations. In this research, Ponni rice grains that had been stored for a year were examined to identify alterations in physical properties and their interconnections under the stress of infestation. This research focuses on the study of the physical properties of the Ponni rice and correlation between different parameters. The results suggest a strong correlation among grain size parameters, whereas the shape descriptors exhibit a less pronounced relationship. Grasping these connections contributes to better milling efficiency, improved storage longevity, and enhanced market appeal of rice grains. These findings offer important perspectives for engineers, agronomists, and food processors seeking to optimize postharvest management and product quality.

Keywords: Correlation, grain volume, insect infestation, Ponni rice, sphericity

1. Introduction
India has increased its total production of food grains by nearly 300 percent, rising from 76.67 million tonnes (mt) to more than 308 million mt (Anonymous, 2021) [2]. Grain storage plays a role in the grain marketing supply chain by moderating variations in grain supply between seasons, typically around the harvest time, and from prosperous years to those with less availability. Storage of grains can occur at different levels, including farms, merchants, corporations, or government facilities (Said & Pradhan, 2014) [16]. The physical and engineering characteristics of rice grains, including length (L), breadth (B), and thickness (T), are essential in influencing grain quality and storage effectiveness. These dimensional aspects affect packing density, airflow resistance, and heat transfer during storage, which directly impacts rice preservation (Dangi *et al*., 2021) [4]. Consistent grain dimensions facilitate improved stacking and decrease interstitial spaces, thereby lowering the chances of hotspots that encourage mold development and pest activity. Moreover, differences in grain size can affect milling yields, as broken grains are more vulnerable to pest infestation due to their larger exposed surface area (Battacharya, 1985) [3].
Sphericity (Φ) is another important characteristic that influences the movement and packing behavior of rice grains within storage systems. Grains with lower sphericity values, which signify elongated shapes, may result in uneven distribution in silo, creating areas where insects can flourish. Additionally, sphericity affects the efficiency of cleaning and sorting equipment since irregularly shaped grains might evade mechanical separation, heightening the risk of contaminated batches. By measuring sphericity, storage managers can devise improved grain handling systems that reduce pest entry points and enhance aeration efficiency (Varnamkhasti *et al*., 2008a) [18].

Bulk density (ρb) and true density (ρt) are vital engineering characteristics that influence the compactness and porosity of stored rice grains. The bulk density affects the capacity of silos for storage, whereas true density is used to evaluate grain purity and maturity (Puramshetty *et al*., 2025) [14]. A low bulk density typically signifies greater porosity, which can improve airflow but also create hiding spots for pests. On the other hand, overly dense packing can hinder ventilation, resulting in moisture buildup and fungal development. The ratio of bulk to true density reflects the amount of interstitial air space, which is crucial for fumigation efficiency since pests often inhabit these spaces. Therefore, optimizing these densities is essential for achieving suitable storage conditions that discourage infestation while preserving grain quality (Anjali *et al*., 2023) [1].

Moisture content (MC) is one of the most significant elements in rice storage since it directly affects grain respiration, microbial development, and insect multiplication. Elevated moisture levels speed up metabolic processes in grains, causing heat production and deterioration (Kumar & Kalita, 2017) [8]. Pests like *Sitophilus oryzae* flourish in humid settings, making moisture management essential for preventing infestations. Additionally, MC impacts grain hardness, with drier grains being less vulnerable to insect penetration. Therefore, maintaining ideal moisture levels through adequate drying and monitoring is crucial for preserving long-term storage stability.

The angle of repose is an important engineering attribute that reveals the flow properties of rice grains during storage and handling. A higher angle suggests inadequate flowability, which can result in uneven distribution within storage bins and the potential segregation of damaged grains (Jia *et al*., 2014) [6]. Damaged grains attract pests because of their increased exposed surface area and accessibility to nutrients. Furthermore, grains with a steep angle of repose may develop clumps, making it difficult for fumigants to penetrate during pest control efforts. By assessing this property, storage facilities can configure hopper angles and conveyor systems appropriately to facilitate smooth grain movement, lowering the risk of infestations associated with stagnant or poorly ventilated areas.

The arithmetic mean diameter (Am) and geometric mean diameter (Gm) give insights into the average dimensions and consistency of rice grains, which are crucial for storage and pest management. Grains that vary in size create voids that allow for easier insect movement and establishment (Tong *et al*., 2019) [17]. Larger grains may also require more time to reach equilibrium in moisture and temperature, increasing the likelihood of localized spoilage. Thie uniformity in grains improves the efficiency of aeration and fumigation, as a consistent grain size distribution fosters even airflow and chemical distribution, thereby lowering pest survival rates.

Grain volume and surface area are essential for assessing rice's vulnerability to insect infestation. Larger surface areas lead to increased exposure to environmental factors, such as humidity and pests (Pandiselvam *et al*., 2016) [13]. Insects like *Tribolium castaneum* (red flour beetles) are attracted to grains with a higher surface-to-volume ratio since they have easier access to the endosperm. Additionally, grain volume influences heat and mass transfer during storage, with smaller grains heating up more quickly, creating conditions favorable for insect reproduction. Thus, the analysis of these properties supports the development of storage protocols that reduce infestation threats.

Incorporating these physical and engineering properties into storage management systems enhances the ability to foresee and mitigate insect infestations. For example, grains with higher true density and lower porosity are less likely to host pests because of the limited interstitial spaces (Kruszelnicka *et al*., 2020) [7]. Additionally, maintaining uniform geometric mean diameters along with optimized moisture levels creates less hospitable conditions for insect reproduction. By utilizing these insights, post-harvest losses can be greatly reduced, supporting food security and economic sustainability.

The objectives of the study were:

- To analyse the physical and engineering properties of local rice grain variety (Ponni rice) from Thanjavur district.
- To analyse the correlation between different physical properties that influences the quality of the rice grains.

2. Materials and Methods

2.1 Raw material

The rice sample (Variety: Ponni rice) procured from local market Udhyam Rice Mill, Thanjavur, TamilNadu, India. In the southern part of Tamil Nadu, ponni rice is a favored variety of semi-polished, parboiled, medium-grain rice that is commonly eaten in and around Tamil Nadu. The work was carried out in Microbiology Laboratory at the Department of Food Packaging and Storage Technology, located at The National Institute of Food Technology, Entrepreneurship and Management in Thanjavur, Tamil Nadu, India. The rice grains were stored for around 1 year before the analysis.

2.2 Physical properties

The physical characteristics, including length (L), breadth (B), Height (H), sphericity (Φ), bulk density (ρb), true density (ρt), moisture content (MC), arithmetic mean diameter (Ad), and geometric mean diameter (Gd), were assessed for rice samples. Standard methods and protocols were utilized to determine these parameters.

2.2.1 Grain dimensions

To determine the physical characteristics of the rice and millet samples, we carefully measured their length (L), width (W), and thickness (T) using precision tools—a vernier caliper for smaller grains and a measuring scale for larger ones. These fundamental dimensions provide the basis for understanding grain morphology and its influence on processing and storage.

2.2.2 Sphericity

Sphericity helps us quantify how closely a grain's shape resembles a perfect sphere. We calculated this property using the formula (Equation 1) developed by (Mohsenin, 1970) [12], which compares the grain's actual dimensions (length (L), width (W), thickness (T)) to an ideal sphere with equivalent volume. This measurement is particularly valuable for predicting how grains will behave during handling and processing.

$$\text{Sphericity} = \frac{(\text{LWT})^{1/3}}{\text{L}} \times 100 \quad (1)$$

2.3.2 Density and Porosity

We employed two approaches to measure density,

Bulk Density: The bulk density (kg/m^3) of the rice grains were measured by gently filling a standardized 100ml container with grains from a 10cm height to ensure natural packing, then weighing the final weight of the contents and the bulk density was calculated using the equation (2)

$$\text{Bulk density} = \frac{\text{Mass of the rice grain}}{\text{Volume of the container}} \quad (2)$$

True Density: The true density of the grains was determined through liquid displacement, where we submerged 50g samples in toluene (25ml) and measured the volume they displaced and the true density was calculated using the formula (3)

$$\text{True Density} = \frac{\text{Mass of the rice grain}}{\text{Volume of the toluene displaced}} \quad (3)$$

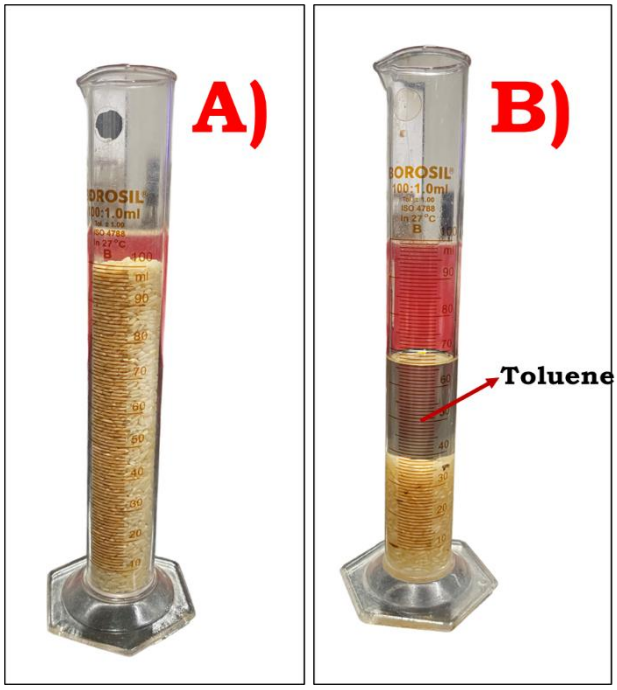


Fig 3.1: (A) Bulk density measurement B) True density measurement

From these density measurements, we calculated porosity—the percentage of empty space between grains—using the established relationship (Equation 4) between bulk and true density. These properties significantly impact storage capacity and grain stability.

$$\text{Porosity} = \left(1 - \frac{\text{Bulk density}}{\text{True density}}\right) \text{x } 100 \quad (4)$$

Five replicates of the rice grains were measured and the average value was considered.

2.3.3 Moisture Content Analysis

Using an infrared moisture analyzer, we precisely measured moisture levels by heating 5 g samples at 110 °C until they reached constant weight. This process, repeated five times for accuracy, helps to determine the grain's stability during storage, as moisture content directly affects shelf life of the grains and susceptible to spoilage.

Fig 3.2: Infrared Moisture Balance

2.3.4 Mean Diameters

We computed two types of average grain sizes

Arithmetic Mean Diameter (mm): A simple average of length, width, and thickness was calculated using the following relation (5)

$$\text{Am} = \frac{l+w+t}{3} \quad \ldots (5)$$

Geometric Mean Diameter (mm): A more sophisticated measure that better represents irregularly shaped grains by considering all three dimensions multiplicatively with the following relationship (6)

$$\text{Gm} = \sqrt[3]{l} \text{ x } w \text{ x } t \quad \ldots (6)$$

These calculations provide valuable insights into grain size distribution, which affects everything from milling efficiency to packaging requirements.

2.3.5 Grain volume and Surface area

The grain volume (Vg) refers to the amount of space that individual grains occupy or their size distribution. The grain volume was determined by applying equation (7). The surface area (Sa) of the grains was calculated using equation (8). These characteristics of the grains affect the milling yield and their moisture absorption during storage (Jain & Bal, 1997) [5].

$$\text{Vg} = 0.25[\left(\frac{\pi}{6}\right) \text{ L}(\text{B} + \text{T})^2 \quad (7)$$

$$\text{Sa} = \frac{\pi W l^2}{(2l - W)} \quad (8)$$

Where,

$$W = \sqrt{bt} \quad (9)$$

2.3.6 Aspect ratio

The aspect ratio is a dimensionless parameter that represents the ratio of a grain's width to its length, indicating whether the grain is elongated or round (Equation 3.10). A value close to 1 suggests spherical grains, while a value greater

than 1 indicates more slender grains (Maduako & Faborode, 1990) [9].

$$Ar = \frac{B}{L}$$

2.4 Statistical analysis
The statistical analysis of physical properties of rice grains was analysed using SPSS software (Version 22.0).

3. Results and discussion
3.1 Measurement of morphological parameters of rice grains: The following parameters mentioned in Section II was measured and calculated by following the standard protocols. The means, medians, standard deviation, standard error, Maximum and minimum value for Length, Breadth, Height, Sphericity, Aspect ratio, Arithmetic mean diameter, Geometric mean diameter, Grain volume, Surface area, Bulk density, True density, Porosity, Moisture content was summarised in Table 1. For the Ponni rice variety, the overall mean values were around 5.402 mm for length, 1.481 mm for breadth, 1.401 mm for thickness, and aspect ratio was around 3.653. These values were in accordance with the previous research findings (Kruszelnicka *et al.*, 2020) [7].

Table 1: Physical properties of Rice grains (Ponni rice)

Length (mm)	Breadth (mm)	Thickness (mm)	Sphericity	Aspect ratio	AMD	GMD	Grain volume	SA
5.56	1.62	1.4	0.418631	0.291367	2.86	2.327587	6.630257	15.21502
5.27	1.37	1.43	0.413186	0.259962	2.69	2.177488	5.402172	13.3627
5.62	1.64	1.24	0.400803	0.291815	2.833333	2.252513	6.09485	14.42007
5.1	1.46	1.35	0.423171	0.286275	2.636667	2.15817	5.265317	13.0437
5.02	1.38	1.39	0.423801	0.2749	2.596667	2.127482	5.036223	12.67048
5.12	1.46	1.37	0.424142	0.285156	2.65	2.171606	5.361478	13.19875
5.35	1.4	1.52	0.420489	0.261682	2.756667	2.249616	5.964323	14.19612
5.13	1.37	1.23	0.400065	0.267057	2.576667	2.052332	4.534253	11.97717
5.36	1.53	1.4	0.420885	0.285448	2.763333	2.255943	6.01647	14.27254
6.11	1.5	1.49	0.3912	0.245499	3.033333	2.390229	7.142089	16.35045
5.78	1.62	1.48	0.415566	0.280277	2.96	2.401973	7.262613	16.23482
5.43	1.39	1.38	0.40219	0.255985	2.733333	2.183892	5.447548	13.5417
5.63	1.64	1.44	0.420788	0.291297	2.903333	2.369036	6.983152	15.74036
5.08	1.3	1.33	0.406153	0.255906	2.57	2.063255	4.594274	12.05394
5.57	1.47	1.5	0.414222	0.263914	2.846667	2.307214	6.424063	14.99219
5.6	1.59	1.39	0.413059	0.283929	2.86	2.31313	6.502229	15.0806
5.35	1.46	1.37	0.411897	0.272897	2.726667	2.203649	5.602326	13.6973
5.32	1.48	1.51	0.429014	0.278195	2.77	2.282356	6.218644	14.53655
5.24	1.57	1.43	0.434035	0.299618	2.746667	2.274341	6.16617	14.39233
5.41	1.37	1.38	0.401238	0.253235	2.72	2.170696	5.349391	13.38746

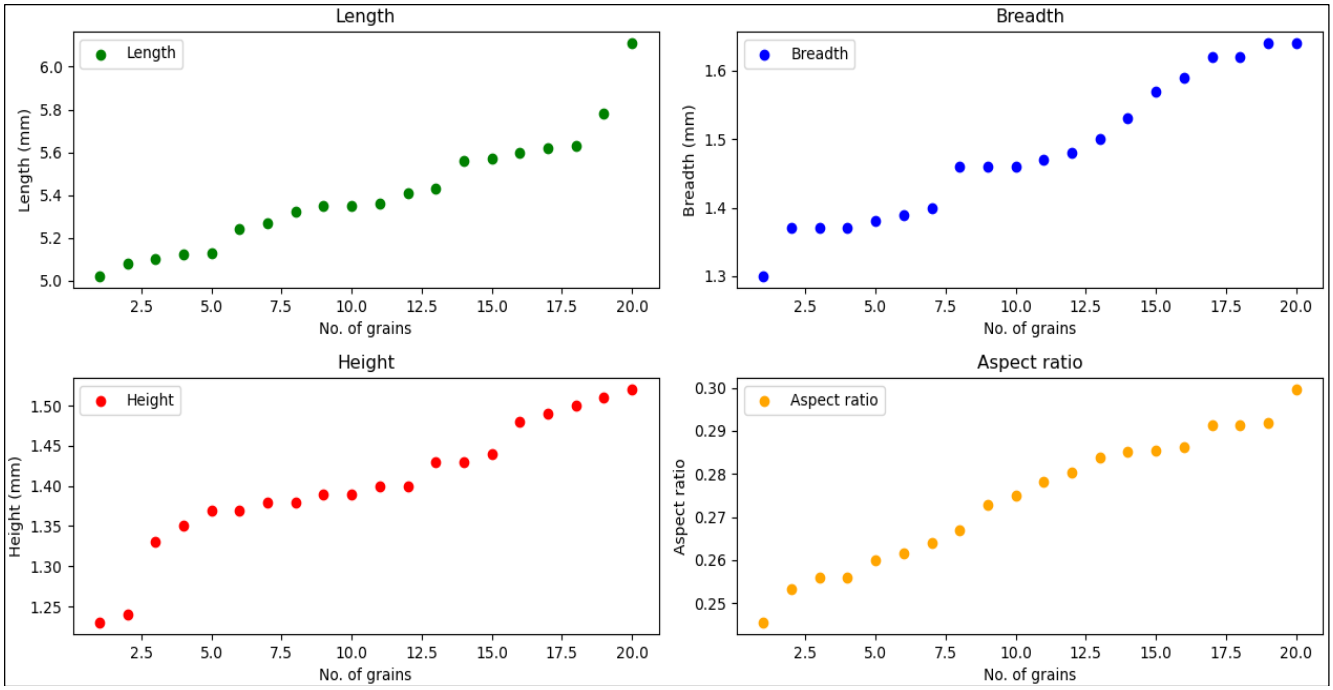


Fig 1: Relationship between some physical properties (Length, breadth, thickness, aspect ratio)

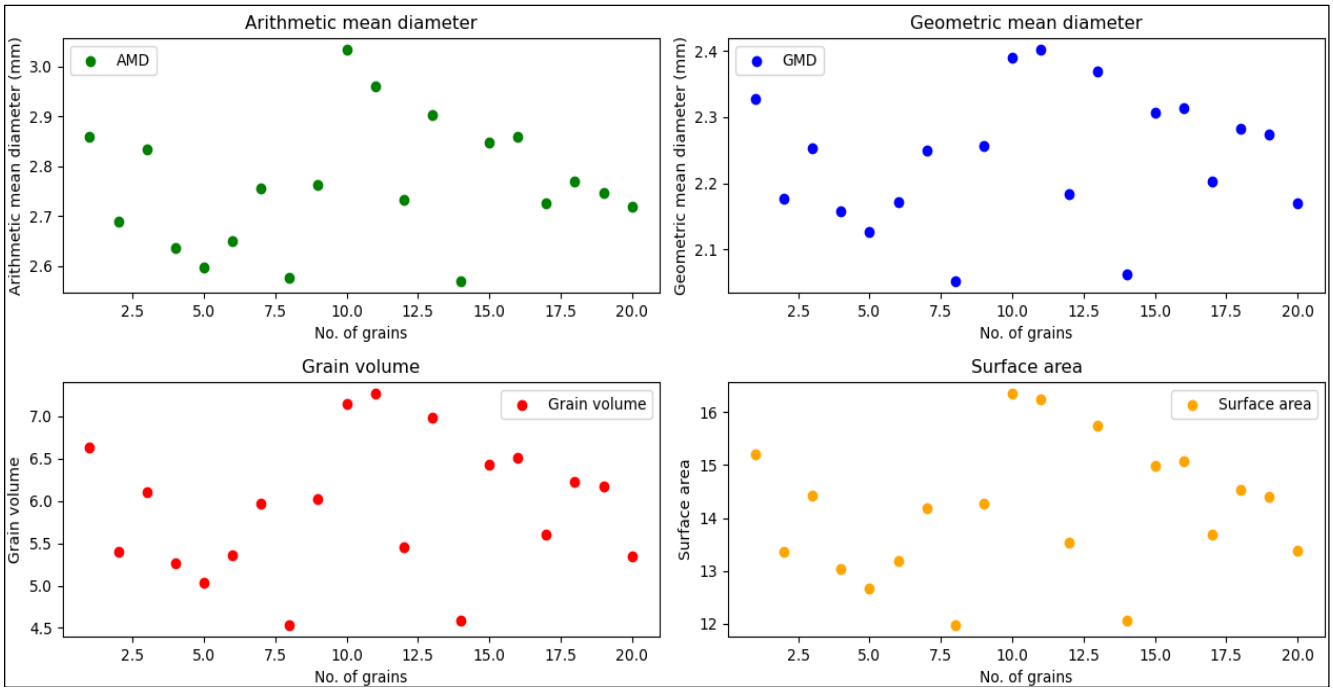


Fig 2: Variation in Arithmetic Mean Diameter (AMD) (mm), Geometric Mean Diameter (GMD)(mm), Grain Volume (mm^3), and Surface Area (mm^2) of 20 Individual Ponni Rice Grains.

From Fig.1, it was analysed that the Length, breadth, height and aspect ratio have linear relationship with the number of grains. All these parameters confirmed that the Ponni rice belongs to the medium length rice. From the mean value of aspect ratio, the selected ponni rice grains was categorized into short slender rice according to (Mahale & Korde, 2014) [10]. The grains are in the slender form in respect to the aspect ratio. The sphericity value was around 0.41 which is in accordance with previous literature works by Mohsenin (1970) [12] as most of the agricultural materials have the range of 0.33 to 1.

The mean value of the moisture content was around 10.28% as the optimum moisture content of the rice would reduce from 12% to 10% as the rice stored for more than one year. This value was in accordance with the literature (Sahay & Singh, 1996). Bulk density values help in development of silos. The mean value of the bulk density was around 863.333 $kg/m^{3.}$ The mean value of the porosity was calculated as 42.4% which is in accordance with the previous research work. During forced convective drying, the resistance offered to the air combustion product mixture would be less for the high porosity grains that results in faster drying time (Varnamkhasti *et al*., 2008) [19].

The physical characteristics of rice grains—such as arithmetic mean diameter, geometric mean diameter, volume, and surface area—show a uniform distribution among 20 samples (Fig.2). The mean grain volume and geometric mean diameter was calculated as 5.899 mm^3 and 2.236mm. A robust positive correlation was found between the geometric mean diameter and grain volume, confirming that size consistency plays a crucial role in volumetric expansion in grains. The surface area of the sample was found to 14.11 mm^2. The surface area exhibited a comparable trend, which further corroborates the link between grain bulk and the external area of the grains. The surface area and the grain volume values confirmed that the ponni rice sample was categorized in medium to bold rice variety.

3.2 Correlation studies between different parameters

The Correlation coefficient between different physical properties were presented in Fig. 3.

3.2.1 Correlation between Sphericity and aspect ratio

From the Fig. 3, the sphericity and aspect ratio showed a negative correlation between each other which was confirmed with the equation y=−1.09x+4.11. The negative slope indicates as the sphericity increases with the decrease in aspect ratio. The Correlation coefficient was around 0.0135. This value suggested that the influence of these two parameters on the grain quality was found to be minimal. The pearson coefficient was calculated as -0.0444 which confirmed a weak relationship between these two parameters.

3.2.2 Influence of length on grain volume

Fig.3 shows that there is a positive correlation between the length and the grain volume of the grains which could be seen from the equation y=2.76x+9.02 which indicates that as the length of the rice grains increases, their grain volume tends to increase significantly. The R^2 value of 0.8961 indicates that around 89.6% variation in the grain volume could be explained by the variation in grain length. Fig.3 still demonstrates that length continues to have predictive capability for assessing volume. This relationship is essential for evaluating quality since longer grains are typically favored in high-end rice markets.

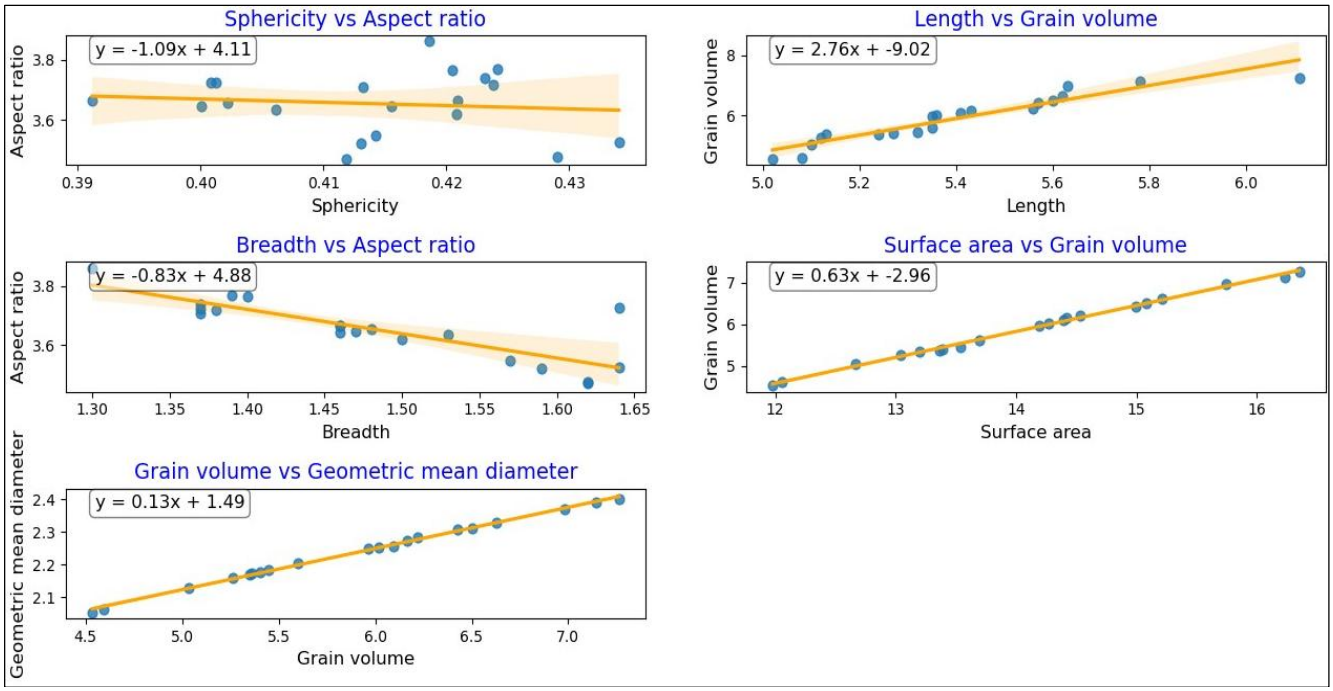


Fig 3: Graphs showing Correlation between different physical parameters of Ponni rice grains

3.2.3 Relationship between breadth and aspect ratio

The relation between breadth and aspect ratio showed a moderate correlation which was evident from Fig.3. The following equation y=-0.83x + 4.88 shows that there is a negative correlation between these two parameters and correlation coefficient was around 0.6881. This is logically and morphologically understandable because the aspect ratio is calculated as length divided by breadth; therefore, any increase in breadth (while keeping length relatively unchanged) leads to a decrease in the ratio. Insects can cause uneven abrasion of the grains' breadth, either by swelling certain parts or by reducing breadth through edge chipping. The correlation continues to be significant, suggesting that breadth is a dependable inverse predictor of aspect ratio in infested grains (Mehta & Kumar, 2021) [11].

3.2.4 Interrelation of Surface Area and Volume

The stronger correlation coefficient R^2=0.9961 shows that there is perfect correlation between surface area and volume of the grains which was confirmed with the equation y=0.63x+ -2.96. This indicates as the surface area of grains increases, the volume of the grains increases proportionally. This is consistent with geometric principles, as larger grains exhibit increased surface exposure. Even with insect infestation, which may damage surface textures, the general trend continues to be robust. This is probably due to the fact that volume and surface area grow in a similar manner with increases in grain size, even if minor roughness occurs.

3.2.5 Geometric scaling of grain volume with geometric mean diameter (GMD)

An exceptionally high positive correlation between grain volume and geometric mean diameter shows that these two parameters are linearly correlated which is evident from the equation y=0.13x+1.49 and R^2 value of 0.9974. GMD, which represents a combination of length, width, and thickness, serves as an indicator of overall grain size, consequently showing a strong correlation with volume. Even in cases of slight degradation caused by insects, as long as the damage is symmetrical, GMD usually reflects the "average bulk size" accurately. Thus, both volume and GMD continue to be dependable measures of overall grain size in morphometric studies.

4. Conclusion

The research investigated the physical characteristics of Ponni rice grains by examining the relationships among various morphological factors. The key parameters that were assessed included length (ranging from 5.92 to 6.38 mm), breadth (spanning 2.01 to 2.26 mm), grain volume (from 8.41 to 10.56 mm^3), geometric mean diameter (between 3.38 and 3.59 mm), and surface area (varying from 35.9 to 40.5 mm^2). The correlation findings revealed a strong positive correlation between grain volume and aspects such as length (R^2=0.8961), surface area (R^2=0.9961), and geometric mean diameter (R^2=0.9974), indicating that these measurements can reliably predict grain size. In contrast, factors like sphericity and aspect ratio exhibited a weaker correlation (R^2=0.0135), suggesting significant variability likely influenced by insect damage and grain deterioration during storage. This study highlights the significance of monitoring physical properties to evaluate rice grain quality during storage, as insect infestation and moisture loss can affect grain dimensions. The strong correlations among the parameters offer important insights for grain grading and processing, while the weaker correlations underline the necessity for enhanced quality control measures to address deterioration related to storage.

This research enhances post-harvest management approaches by demonstrating the interconnections between physical properties and examining the storage conditions might affect these associations, ultimately assisting in maintaining the quality of rice grains.

5. References

1. Anjali PN, Bosco SJD, Navaf M, Sunooj KV. Physical properties of cereal grains. In: Cereal Grains. Boca Raton: CRC Press; 2023. p. 25-47.
2. Anonymous. Time to redefine grain storage in India. The Hindu 2021

https://www.thehindubusinessline.com/economy/agri-business/time-to-redefine-grain-storage-in-india/article37297550.ece
3. Battacharya KR. Parboiling of rice. In: Rice Chemistry and Technology. St. Paul: America Association of Cereal Chemists; 1985. p. 285-348.
4. Dangi P, Chaudhary N, Gupta A, Garg I. Rice processing and properties. In: Handbook of Cereals, Pulses, Roots, and Tubers. Boca Raton: CRC Press; 2021. p. 71-88.
5. Jain RK, Bal S. Properties of pearl millet. Journal of Agricultural Engineering Research. 1997;66(2):85-91.
6. Jia F, Han Y, Liu Y, Cao Y, Shi Y, Yao L, *et al*. Simulation prediction method of repose angle for rice particle materials. Transactions of the Chinese Society of Agricultural Engineering. 2014;30(11):254-260.
7. Kruszelnicka W, Marczuk A, Kasner R, Bałdowska-Witos P, Piotrowska K, Flizikowski J, *et al*. Mechanical and processing properties of rice grains. Sustainability. 2020;12(2):552.
8. Kumar D, Kalita P. Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods. 2017;6(1):8.
9. Maduako JN, Faborode MO. Some physical properties of cocoa pods in relation to primary processing. Ife Journal of Technology. 1990;2(1):1-7.
10. Mahale B, Korde S. Rice quality analysis using image processing techniques. In: International Conference for Convergence for Technology-2014; 2014. p. 1-5.
11. Mehta V, Kumar S. Relative susceptibility and influence of different wheat cultivars on biological parameters of *Sitophilus oryzae* L. (Coleoptera: Curculionidae). International Journal of Tropical Insect Science. 2021;41(1):653-661.
12. Mohsenin NN. Physical properties of plant and animal materials. Volume 1: Structure, physical characteristics and mechanical properties. New York: Gordon and Breach Science Publishers; 1970.
13. Pandiselvam R, Thirupathi V, Mohan S. Engineering properties of rice.
14. Puramshetty L, Edde M, Bogala P, Kate A. Physical and milling properties. In: Colored Cereals: Properties, Processing, Health Benefits, and Industrial Uses. Boca Raton: CRC Press; 2025. p. 71.
15. Sahay KM, Singh KK. Unit operations of agricultural processing. New Delhi: Vikas Publishing House; 1996.
16. Said P, Pradhan R. Food grain storage practices - a review. Journal of Grain Processing and Storage. 2014;1:1-5.
17. Tong C, Gao H, Luo S, Liu L, Bao J. Impact of postharvest operations on rice grain quality: A review. Comprehensive Reviews in Food Science and Food Safety. 2019;18(3):626-640.
18. Varnamkhasti MG, Mobli H, Jafari A, Keyhani AR, Soltanabadi MH, Rafiee S, *et al*. Some physical properties of rough rice (*Oryza sativa* L.) grain. Journal of Cereal Science. 2008a;47(3):496-501.
19. Varnamkhasti MG, Mobli H, Jafari A, Keyhani AR, Soltanabadi MH, Rafiee S, *et al*. Some physical properties of rough rice (*Oryza sativa* L.) grain. Journal of Cereal Science. 2008b;47(3):496-501. https://doi.org/10.1016/j.jcs.2007.05.014