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Optimization of flaking techniques for prominent paddy varieties of PJTAU

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Abstract

The present study was undertaken to evaluate the suitability of selected six paddy varieties RNR 28361, RNR 29325, RNR 35008, RNR 35105, RNR 35131, and TELLA HAMSA developed by Professor Jayashankar Telangana Agricultural University (PJTAU), Hyderabad for flakes production, with a focus on optimizing processing parameters and understanding varietal behavior during transformation. Initially, the physical characteristics of the grains including weight, volume, hydration capacity and index, swelling capacity and swelling index were determined to evaluate their water absorption potential and swelling dynamics. Significant varietal differences ($p < 0.05$) were observed among six paddy genotypes for key physical traits including grain weight, volume, hydration and swelling capacities indicating their differential suitability for processing applications. The genotypes exhibited statistically significant differences ($p < 0.05$) in dehulling efficiency and husk removal extent which reflected their varied processing adaptability. The dehulling performance was best observed in Tellahamsa variety at 83.3% while the total output was maximum in RNR 29325 variety at 67.42%. Similarly significant difference was observed in the flattening ability of the flakes. Maximum complete flattening was reported in RNR 35008 at 46.4%. Specific flaking behavior was shown by paddy varieties for flake morphology. This insight not only facilitates the creation of value-added products with optimized texture and moisture characteristics but also guides the targeted selection of grain varieties aligned with consumer expectations and compatible processing methods.

Keywords: “Beaten Rice”, “Flaking Potential”, “Performance Evaluation”, “Paddy Shreds”

Introduction

Paddy (*Oryza sativa*) has been a cornerstone of global agriculture and human civilization for thousands of years. Domesticated as early as 3500 BC, rice cultivation spread across Asia, becoming deeply embedded in the cultural, economic, and dietary fabric of societies from India to Japan and beyond. In India, paddy is not merely a staple crop, it is a symbol of sustenance, tradition, and rural livelihood. The United Nations recognized its global importance by declaring 2004 the “International Year of Rice,” underscoring the fact that over 60% of the world’s population depends on rice as a primary food source [1].

Historically, paddy cultivation evolved through traditional practices passed down generations, often shaped by local agro ecological conditions. However, modern challenges such as climate variability, water scarcity, pest infestations and the need for higher productivity have necessitated the development of new hybrid paddy varieties. These hybrids are bred to combine desirable traits such as drought tolerance, disease resistance, early maturity, and improved grain quality. They not only enhance yield potential but also reduce input costs and improve resilience, making them vital for sustainable agriculture and food security [2].

Parallel to genetic advancements, there is a growing emphasis on value addition in rice processing. Traditional rice consumption patterns are shifting due to urbanization, changing lifestyles and increased demand for ready-to-eat and nutritionally enriched products. Among these, rice flakes commonly known as *poha*, *aval*, or *atukulu* have emerged as a versatile and culturally significant product. Produced by soaking, roasting, and flattening paddy grains, rice flakes are widely consumed across India and Southeast Asia as breakfast cereals, snacks, and

ingredients in savoury dishes [3, 4].

From a nutritional standpoint, rice flakes offer several advantages. They are gluten-free, easily digestible and rich in carbohydrates, iron, and B-complex vitamins such as thiamine and niacin. Brown rice flakes, in particular, retain higher fiber and mineral content due to minimal polishing. Their low glycemic index and antioxidant properties make them suitable for diabetic and health-conscious populations. Moreover, rice flakes can be fortified or blended with other grains and legumes to enhance their functional properties, making them ideal for community nutrition programs and commercial product development [3].

In this context, the present study was designed to evaluate the flakes production potential of six paddy varieties developed by Professor Jayashankar Telangana Agricultural University (PJTUA), Rajendranagar, Hyderabad. The work involved assessing grain physical properties, optimizing processing parameters such as roasting and pressing time, quality assessment and functional attributes of the produced flakes. The findings aimed to support the development of standardized, scalable flakes production protocols and promote the use of regionally adapted paddy hybrids in value-added food systems.

Materials and Methods

Six paddy varieties RNR 28361, RNR 29325, RNR 35008, RNR 35105, RNR 35131, and TELLA HAMSA were procured from ARI, PJTUA, Rajendranagar, Hyderabad. Paddy grains were utilized to assess their physical characteristics, optimize processing parameters for flakes development, and evaluate the functional properties of the flakes.

Physical properties of grain

1000 randomly picked grains without any distortions were chosen and weighed (0.001g) for 1000 grain weight later transferred to graduated measuring cylinder to measure volume of the same. Hydration index and hydration capacity is calculated before and after grain weight after soaking for 24 hrs. Swelling capacity and swelling index was calculated based on differences in volume of the grain before and after soaking for 24 hours [5].

Dehulling parameters

The outcome of the dehulling process was assessed by analyzing the yields of various output components relative to the initial grain sample weight (g), dehulled grain (dg) and residual husk (h) [6].

Dehulling (%): Dehulling percentage was calculated by dividing the weight of grain retained (in grams) by the total weight of the sample (in grams), and multiplying the result by 100.

Degree of Dehulling [DoD]: The degree of hull removal is the ratio of mass of hull removed during dehulling to the initial mass of sample used for the dehulling process.

$\text{DoD} = \text{Mass of hull} / \text{mass of initial sample}$

Processing of Flakes

Six paddy varieties were initially cleaned to remove physical impurities such as dust, stones, and chaff. The cleaned grains were then soaked in water for 18 hours to facilitate hydration and initiate gelatinization. Post soaking, the grains were carefully decanted to eliminate excess surface moisture and shade-dried for 30 minutes to allow residual water to drip off,

ensuring optimal moisture levels for roasting. The partially dried grains were subsequently roasted to remove internal moisture and loosen the husk, enhancing brittleness for effective flake formation. Roasted grains were then pressed using mechanical disc rollers mounted on an Edge Runner (Make: Mathesis Engineers, Hyderabad), which flattened the grains into flakes. Hulls and other waste materials were separated, and the resulting flakes were evaluated to assess the processing performance and suitability of each paddy variety for flakes production.

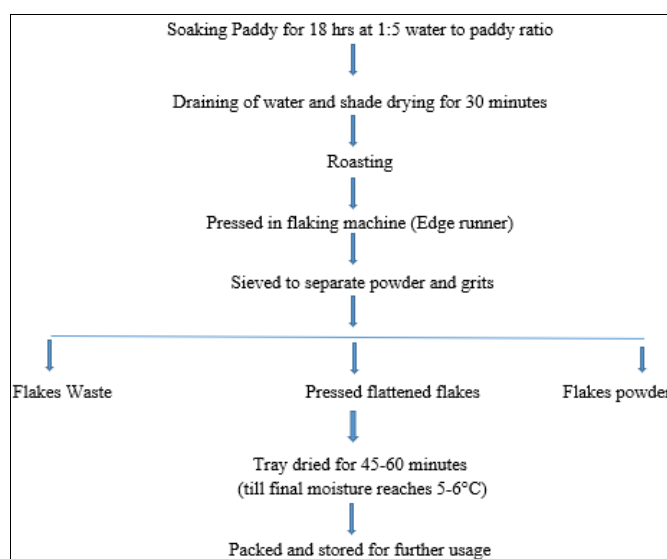


Fig 1: Protocol for flakes processing

Functional parameters of flakes

Swelling index and swelling capacity of flakes were determined following the procedure outlined by Ukpabi and Ndimele [7]. A measured quantity of flakes were placed in a clean graduated cylinder, weighed, and then 50 ml of water was added. After a 3-hour soaking period, the swelling capacity of the flattened flakes was recorded. Water retention capacity was assessed by hydrating one gram of flour with 10 ml of water, followed by centrifugation at 3000 rpm for 20 minutes. The sample was then dried at 105 °C until a constant weight was achieved, and the retained water was quantified based on the difference in pre- and post-drying weights.

Statistical analysis

The Jamovi project statistical software (2024, version 2.6) was used to perform the statistical analysis of the data. Analysis of variance (ANOVA) was performed to determine significant differences at a 5 per cent level of significance.

Results and Discussion

The present study was undertaken to standardize the processing parameters for flake production using six prominent paddy varieties. Initially, the paddy grains were carefully examined for weight, volume, hydration capacity and index, as well as swelling capacity and swelling index to assess their water absorption potential and swelling behavior. These evaluations provided a foundational understanding of each variety's suitability for flake formation. Based on these insights, a series of controlled trials were conducted to optimize key processing parameters such as roasting time and pressing duration.

Each variety was subjected to a series of controlled steps including cleaning, soaking, roasting, cooling, and mechanical pressing. Key variables such as roasting time and pressing duration were optimized to evaluate their influence on flake

yield, hull separation and overall recovery. The results presented below highlight the comparative performance of each variety in terms of flake output, processing efficiency, and suitability for flake-making.

Physical properties of grain

Hydration refers to the regulated diffusion of water into grains during soaking, measured on a wet basis. To evaluate the water absorption behavior of grains, it is essential to analyze physical properties such as hydration capacity, hydration index, swelling capacity and swelling index and results mentioned in Table 1.

In the present study, the variety RNR 35008 exhibited the highest 1000-grain weight whereas RNR 35105 recorded the lowest 1000-grain weight. The significant difference at 5% significant level was observed for 1000 grain weight ($p = 0.014$) while RNR 35008 stood out with the highest 1000-grain volume

and Tellahamsa showed the lowest, the results indicated a significant difference among the cultivars at the 5% significant level ($p = 0.024$). Tellahamsa exhibited the highest values for hydration capacity, hydration index, swelling capacity, and swelling index among all tested varieties. There was significant difference at 5% among paddy varieties for hydration capacity ($p = 0.015$) and swelling capacity ($p = 0.013$) while the significant difference was observed at 1% for hydration index ($p = 0.006$) and swelling index ($p = 0.007$). Studies have shown that the hydration kinetics of paddy grains were influenced by factors such as temperature, grain morphology, and chemical composition including amylose and starch content which vary across cultivars and affect water uptake efficiency. These parameters reflect the grain's ability to absorb moisture and its resistance to water penetration, particularly when a thick paddy husk acts as a barrier.

Table 1: Physical properties of grain

Physical Properties of grain	RNR 28361	RNR 29325	RNR 35008	RNR 35105	RNR 35131	TELLA HAMSA	p- value
1000 grain weight (g)	26.84 ± 0.72	28.60 ± 0.10	33.33 ± 5.44	26.28 ± 0.57	26.98 ± 0.10	26.30 ± 0.20	0.014*
1000 grain volume (ml)	41.77 ± 0.23	41.07 ± 1.04	48.20 ± 1.93	44.0 ± 4.58	44.73 ± 2.00	40.05 ± 1.29	0.024*
Hydration capacity (g)	11.90 ± 0.62	10.63 ± 0.75	8.87 ± 0.78	12.02 ± 1.28	9.57 ± 0.80	13.12 ± 0.85	0.015*
Hydration index (%)	44.32 ± 0.79	39.09 ± 1.56	28.07 ± 0.97	45.65 ± 1.35	35.86 ± 1.18	52.55 ± 1.31	0.006**
Swelling capacity (ml)	11.02 ± 1.09	6.83 ± 0.93	7.50 ± 0.69	10.03 ± 1.05	8.67 ± 0.66	11.28 ± 1.08	0.013*
Swelling index (%)	26.26 ± 1.33	16.58 ± 1.05	14.88 ± 1.11	22.22 ± 1.30	20.44 ± 1.21	27.53 ± 1.16	0.007**

*- Significance at 5% level; **- Significance at 1% level

Paddy grain comprises two principal anatomical components: the caryopsis (brown rice) and the protective husk, with an intermediate bran layer encapsulating the endosperm. The intricate multilayered structure, combined with cultivar-dependent variability in physicochemical attributes such as moisture content, grain hardness, and thermal properties poses operational challenges in post-harvest processing, mechanical handling, and long-term storage [8]. These complexities necessitate precise control of environmental and mechanical parameters to ensure quality retention and process efficiency [9]. The presence of a dense husk layer can significantly impede water diffusion, necessitating optimized soaking conditions to

overcome this resistance and enhance processing outcomes like parboiling efficiency and milling quality.

Dehulling Performances

Dehulling is a critical post-harvest operation that involves the mechanical removal of the outer husk from paddy grains to expose the edible brown rice kernel. A complex interplay of grain characteristics, machine parameters, and pre-treatment methods influences the efficiency of this process. The performance of different paddy varieties in dehulling operations is largely dictated by their inherent structural and compositional traits.

Table 2: Dehulling performances of paddy varieties

	RNR 28361	RNR 29325	RNR 35008	RNR 35105	RNR 35131	TELLAHAMSA	p – value
Dehulling (%)	72.70 ± 0.91	81.30 ± 0.98	80.70 ± 1.28	80.0 ± 1.04	79.30 ± 1.25	83.3 ± 1.29	0.021*
Degree of dehulling (%)	27.30 ± 0.97	18.70 ± 1.24	19.30 ± 1.41	20.0 ± 1.81	20.70 ± 1.69	16.70 ± 1.03	0.022*

*- Significance at 5% level

The paddy grains were subjected to dehulling in centrifugal dehuller and results were reported in Table 2. Dehulling percentage represents the proportion of husk effectively removed from the paddy grain during processing. Among the evaluated cultivars, Tellahamsa demonstrated the highest dehulling efficiency at 83.33%, indicating superior husk separation. Conversely, the degree of dehulling reflects the residual husk content post-processing, where lower values denote more thorough dehulling. Tellahamsa recorded the lowest degree of dehulling at 16.67%, underscoring its enhanced

husk removal capability and minimal residual husk. These attributes render Tellahamsa particularly well-suited for mechanical dehulling and downstream milling operations, contributing to improved processing efficiency and product quality. RNR 28361 reported lower efficiency in terms of dehulling output and it might be due to tight husk adhesion or higher grain hardness [10]. The significant difference at 5% was observed for both dehulling ($p = 0.021$) and degree of dehulling ($p = 0.022$).

Table 3: Correlation Between Functional Properties of Paddy Grains and Dehulling Parameters

Functional Property	Dehulling% (r)	df	p -value	Degree of Dehulling% (r)	df	p - value
Hydration capacity (g)	- 0.006	16	0.983 ^{NS}	0.072	16	0.777 ^{NS}
Hydration index (%)	0.050	16	0.843 ^{NS}	-0.044	16	0.863 ^{NS}
Swelling capacity (ml)	- 0.210	16	0.402 ^{NS}	0.264	16	0.290 ^{NS}
Swelling index (%)	- 0.251	16	0.315 ^{NS}	0.247	16	0.323 ^{NS}

^{NS} - Not significant

Correlation analysis as shown in Table 3 revealed that neither dehulling percentage nor degree of dehulling showed significant relationships with hydration capacity, hydration index, swelling capacity and swelling index in the studied samples, as all correlation coefficients were low and p-values non-significant. The results are in agreement with existing literature on cereals where functional properties like water absorption and swelling are primarily influenced by the inherent starch and protein composition, as well as the presence of fiber rather than by the dehulling process itself [11].

Production output of paddy varieties during flaking process

Six prominent paddy varieties were evaluated to standardize the flakes production process and to assess their suitability for flake-making based on grain performance and processing efficiency. Table 4 represented the comparative evaluation of performance of six paddy varieties. Each variety was subjected to standardised and controlled processing conditions and output was analysed in terms of flake yield, hull separation, wastage

and overall recovery percentage.

Roasting

Roasting also loosens the husk and makes the grains brittle, facilitating flake formation. The roasting duration varied across different varieties, likely due to differences in husk composition and the physiological structural integrity of the grains. Prolonged roasting can lead to over-burning and complete loss of the absorbed moisture. Therefore, multiple trials were conducted to standardize the optimal roasting time for each grain variety, with the results presented in Table 4. Roasting time varied significantly across varieties ($p = 0.011$) ranging from 4 min 12 sec (RNR 35008) to 13 min (RNR 28361). RNR 28361 required the longest time but still achieved maximum output percentage (61.03%) indicating good thermal tolerance and flake forming potential. Longer roasting times might be due to variation in husk composition and grain physiological structure and has affected moisture retention.

Table 4: Flake Processing performance of paddy varieties

	RNR 28361	RNR 29325	RNR 35008	RNR 35105	RNR 35131	TELLA HAMSA	p- value
Roasting time (min)	13.04 ± 1.41	5.10 ± 1.25	4.12 ± 1.08	9.58 ± 1.57	7.04 ± 1.44	9.28 ± 1.00	0.011*
Pressing time (sec)	68.05 ± 1.27	100.00 ± 1.32	100.00 ± 1.73	67.00 ± 1.56	72.00 ± 1.39	108.33 ± 0.87	0.008**
Input (g)	135.00 ± 1.00	292.00 ± 0.50	276.00 ± 0.50	280.00 ± 0.66	276.00 ± 0.66	200.00 ± 0.901	0.007**
Weight of flakes (g)	48.00 ± 1.00	120.00 ± 1.80	98.00 ± 0.66	78.00 ± 1.80	62.00 ± 0.50	88.00 ± 1.32	0.005**
Weight of hull (g)	26.00 ± 1.00	114.00 ± 1.32	88.00 ± 1.14	76.00 ± 1.63	64.00 ± 1.32	88.00 ± 1.14	0.006**
Wastage (g)	50.05 ± 0.98	10.00 ± 0.50	38.00 ± 1.56	66.00 ± 1.32	18.00 ± 1.32	14.00 ± 1.63	0.005**
Total output (g)	125.03 ± 0.30	244.00 ± 1.32	224.00 ± 1.09	188.00 ± 1.32	144.00 ± 0.90	190.00 ± 2.17	0.006**
Total output (%)	61.03 ± 0.73	67.42 ± 0.68	52.13 ± 0.87	38.24 ± 0.68	29.25 ± 1.03	56.05 ± 1.24	0.005**

*- Significance at 5% level; **- Significance at 1% level

Roasted paddy was allowed to retain warmth but still cooled to stabilise its structure, prevent over-processing and prepare it for pressing.

Pressing

The roasted and cooled paddy was pressed using mechanical disc rollers to flatten the grains into flakes. While pressing facilitates flake formation, the duration and applied pressure can significantly influence flake thickness and overall yield [12]. In this study, pressing time was standardized for each paddy variety (Table 4), as the time spent during pressing plays a crucial role in determining flake integrity and the efficiency of hull separation. The final product's output and quality were assessed based on the weight of flakes obtained and the amount of wastage, which together determined the overall recovery efficiency.

Pressing time ranged from 67 to 108 seconds with longer durations associated with quality flake formation. Tellahamsa, RNR 29325 respectively exhibited 108 and 100 seconds pressing time and high output percentages (56.0% and 67.42%) whereas the lowest pressing time was observed in RNR 28361. The results showed a statistically significant difference at 1% in pressing time among the varieties ($p = 0.008$).

Flake yield

RNR 29325 produced highest flake weight (120 g) and the highest total output percentage (67.42%) indicating superior suitability for flake production. RNR 35131 yielded 62 g flakes and yielded lowest output percentage (29.25%). Paddy husk weight varied from 26 g (RNR 28361) to 114 g (RNR 29325)

due to differences in husk thickness and separation efficiency. Wastage recorded a maximum in RNR 35105 (66 g) and RNR 28361 (50 g) which indicated grain breakage or inefficient separation of husk during processing. As per output and efficiency RNR 29325 emerged as the most efficient variety with the highest total output (244 g) and recovery percentage (67.24%). RNR 35131 and RNR 35105 showed lower recovery rates, suggesting limited suitability for flake production. There was significant difference at 1% in flake yield across the varieties.

Table 5: Correlation Between Dehulling Performances and Output of Paddy Varieties

Parameter	Total Output% (r)	df	p-value
Dehulling (%)	-0.073	16	0.775 ^{NS}
Degree of Dehulling (%)	0.074	16	0.769 ^{NS}

^{NS} - Not significant

The correlation between total output percentage and dehulling performance in paddy varieties shows very weak relationships as shown in Table 5. The correlation coefficients are close to -0.073 for dehulling (%) and 0.074 for degree of dehulling (%) and high p-values (0.775 and 0.769 respectively) are observed. This indicates that these correlations are not statistically significant. This also suggests that variations in dehulling percentages do not considerably affect the total output yield of paddy under the studied conditions. Such findings align with literature where paddy output depends more on cultivar characteristics, grain hardness and processing conditions rather than directly on the dehulling percentage itself [13].

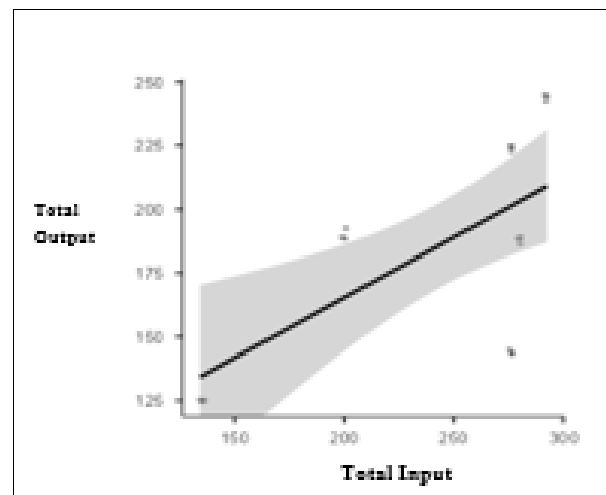
Table 6: Correlation Between Yield of Paddy Varieties and Dehulling Performances

Yield of Paddy Varieties	Dehulling% (r)	df	p-value	Degree of Dehulling% (r)	df	p-value
Weight of Flakes (g)	0.705	16	0.001**	- 0.695	16	0.001**
Weight of Hull (g)	0.849	16	<. 001**	- 0.834	16	<. 001**
Wastage (g)	-0.473	16	0.048*	0.475	16	0.047*

*- Significance at 5% level; **- Significance at 1% level

The correlation analysis shows significant positive relationships between the yield of paddy varieties and key dehulling performance parameters as shown in Table 6. Specifically, weight of flakes correlates positively with dehulling% ($r = 0.705$, $p = 0.001$) and negatively with degree of dehulling ($r = -0.695$, $p = 0.001$). This indicates that higher dehulling percentage generally yields more flakes. Weight of hull also shows strong positive correlation with dehulling% ($r = 0.849$, $p < 0.001$) and negative with degree of dehulling ($r = -0.834$, $p < 0.001$). Wastage correlates negatively with dehulling% ($r = -0.473$, $p = 0.048$) and positively with degree of dehulling ($r = 0.475$, $p = 0.047$) both significant, suggesting that more efficient dehulling reduces wastage. The strong correlations highlight that dehulling percentage is an important factor for improving yield components like flakes and reducing hull waste.

suggests that these particular functional properties do not significantly influence the total output yield of the varieties studied.

**Fig 2:** Correlation Between Total Input and Total Output of Paddy Varieties**Table 7:** Correlation Between Functional Properties and Output of Paddy Varieties

Functional Properties	Total Output% (r)	df	p-value
Hydration capacity (g)	0.225	16	0.368 ^{NS}
Hydration index (%)	0.159	16	0.529 ^{NS}
Swelling capacity (ml)	0.264	16	0.290 ^{NS}
Swelling index (%)	0.010	16	0.969 ^{NS}

^{NS} - Not significant

The correlation analysis between functional properties and total output percentage of paddy varieties indicates weak and statistically non-significant associations (Table 7). Hydration capacity ($r = 0.225$, $p = 0.368$), hydration index ($r = 0.159$, $p = 0.529$), swelling capacity ($r = 0.264$, $p = 0.290$), and swelling index ($r = 0.010$, $p = 0.969$) all showed low correlation values with p-values well above the significance threshold. This

Correlation between total input and total output of paddy varieties is shown in Figure 2. The Pearson correlation coefficient $r=0.649$ with a p-value of 0.004 indicates a statistically significant positive correlation between input and output in the context of paddy processing. Such a significant positive relationship highlights the efficiency and responsiveness of the processing system where better or higher input directly contributes to better yield outcomes.

Table 8: Percentile distribution of flattened flakes for paddy varieties

	RNR 28361	RNR 29325	RNR 35008	RNR 35105	RNR 35131	TELLAHAMSA	p-value
Completely flattened flakes (%)	40.4 ± 1.25	12.7 ± 1.26	46.4 ± 0.71	35.5 ± 1.28	28.8 ± 1.04	38.0 ± 0.10	0.005**
Moderately flattened flakes (%)	37.5 ± 1.17	47.3 ± 0.89	33.5 ± 1.29	25.3 ± 1.09	32.0 ± 0.75	35.2 ± 0.91	0.006**
Broken flakes (%)	23.7 ± 0.27	31.2 ± 0.46	15.0 ± 1.78	27.1 ± 1.72	29.0 ± 0.52	27.7 ± 0.61	0.007**

** - Significance at 1% level

The quality of flakes whether completely flattened, moderately flattened, or broken directly impacts consumer acceptance, cooking behavior and market value. Different paddy varieties respond differently to flaking processes due to their physical and structural properties such as grain hardness, moisture content, and husk adhesion.

The present study compared six paddy varieties based on the weight wise distribution of their output and application of flaking technology on selected paddy cultivars and grains response to it. RNR 35008 exhibited the highest proportion of completely flattened flakes i. 46.4% and the lowest percentage of broken flakes at 15%, reflecting superior flaking efficiency and minimal processing losses. RNR 28361 and Tellahamsa

exhibited lower breakage besides yielded output of completely (40.4% for RNR 28361, 38.0% for Tellahamsa) and moderately flattened flakes (37.5% for RNR 28361 and 35.2% for Tellahamsa) in good proportions. RNR 29325 produced the highest proportion of broken flakes at 31.2%, likely attributable to grain brittleness or insufficient pretreatment. RNR 35131 (32%) and RNR 35105 (25.3%) yielded moderately flattened flakes, indicating a need for process optimization to minimize breakage and enhance output quality. A one-way ANOVA showed a significant difference at 1% among varieties for completely flattened flakes ($p = 0.005$), moderately flattened flakes ($p = 0.006$) and broken flakes ($p = 0.007$).

Table 9: Compressibility dynamics of flattened flakes

Compressibility Dynamics Paddy Varieties	RNR 28361	RNR 29325	RNR 35008	RNR 35105	RNR 35131	TELLA HAMSA	p- value
Completely flattened flakes length (mm)	15.37± 3.28	9.95 ±0.80	17.16± 1.35	13.37± 0.81	13.46±3.59	12.73± 0.83	0.014*
Completely flattened flakes width (mm)	7.53±2.29	5.93 ± 2.57	7.43± 0.85	4.11 ± 0.50	5.68± 3.27	7.27± 0.54	0.016*
Moderately flattened flakes length (mm)	8.73± 0.38	7.02 ± 0.80	7.96± 0.95	8.84 ± 0.89	8.23± 0.68	8.02± 1.15	0.083NS
Moderately flattened flakes width (mm)	6.17± 2.75	5.76 ± 1.17	5.66 ±2.93	6.17 ± 2.02	5.23± 2.54	7.42± 2.52	0.026*
Broken flakes length (mm)	6.99± 2.66	4.86 ± 0.17	7.80± 0.27	7.24 ± 0.62	2.72± 1.30	7.42± 1.52	0.030*
Broken flakes width (mm)	4.24± 0.82	5.14 ± 1.70	7.03± 0.15	1.44 ± 0.51	4.38± 1.84	2.66± 0.63	0.065NS

NS - Not significant; *- Significance at 5% level

RNR 35008 reported largest completely flattened flakes at 17.16 mm indicating better flattening behavior whereas RNR 35131 showed smallest broken flakes at 2.72mm that revealed the grain's fragile nature and poor flaking ability. RNR 28361 and Tellahamsa retained wider flakes when compared with other varieties indicating better grain structure. RNR 35008 and Tellahamsa varieties regained their size and shape whereas RNR

35131 paddy variety need more process optimization for better output. A significant difference was observed at 5% level for completely flattened flakes length ($p = 0.014$), completely flattened flakes width ($p = 0.016$), moderately flattened flakes width ($p = 0.026$) and broken flakes length ($p = 0.030$). Whereas the results were non-significant for moderately flattened flakes length ($p = 0.083$) and broken flakes width ($p = 0.065$).

Table 10: Functional properties of flakes

Functional properties Paddy Varieties	RNR 28361	RNR 29325	RNR 35008	RNR 35105	RNR 35131	TELLA HAMSA	p- value
Swelling index (%)	5.02 ± 1.63	5.15 ± 0.92	5.07 ± 0.80	4.66 ± 0.82	5.62 ± 0.77	4.91 ± 1.23	0.855NS
Swelling capacity (%)	689.00 ± 1.50	690.46 ± 0.54	616.16 ± 0.00	694.28 ± 0.00	652.28 ± 0.00	673.84 ± 0.00	0.005**
Water retention capacity (g/ml)	0.71 ± 0.57	0.37 ± 0.18	1.17± 0.68	0.39 ± 0.15	2.11 ± 0.50	0.58 ± 0.45	0.070NS

NS - Not significant; ** - Significance at 1% level

The comparative analysis of flakes of six paddy varieties revealed differences in their functional properties, which are critical for determining their suitability in various food applications. Among the varieties, RNR 35131 exhibited highest swelling index (5.62%) and water retention capacity (2.118 g/ml), indicating superior hydration and moisture-holding ability ideal for soft-textured or fermented products. RNR 35105 despite, the lowest swelling index (4.66%), exhibited the highest swelling capacity (694.28%), suggesting it absorbs more water by weight but retained less moisture, making it suitable for dry-textured products. Tellahamsa and RNR 28361 showed high swelling capacities (673.84% and 689.0%, respectively) with

moderate water retention, offering balanced hydration for traditional dishes or semi-moist formulations. RNR 29325 presented well-rounded profile with consistent swelling and retention values, making it versatile across multiple applications. In contrast, RNR 35008 showed relatively lower values across all parameters, indicating limited hydration potential and firmer texture post-cooking. There was no significant difference for swelling index and water retention capacity ($p = 0.855$ and $p = 0.070$, respectively), while the swelling capacity showed a highly significant difference at the 1% level ($p = 0.005$). These insights can guide targeted selection of paddy varieties based on desired product characteristics and processing requirements.^{14,15}

Table 11: Correlation between Functional Properties of Flakes and Flake Processing Performance of Paddy Varieties

Functional Properties of Flakes	Roasting Time (r)	df	p-value	Pressing time(r)	df	p-value
Swelling index (%)	- 0.144	16	0.567 ^{NS}	-.0024	16	0.926 ^{NS}
Swelling capacity (%)	0.582	16	0.011 [*]	-0.328	16	0.184 ^{NS}
Water retention capacity (g/ml)	-0.103	16	0.684 ^{NS}	-0.208	16	0.407 ^{NS}

^{NS} - Not significant; * - Significance at 5% level

The correlation analysis for functional properties of flakes reveals that roasting and pressing times have limited significant effects on most functional attributes as shown in Table 11. Swelling index showed no significant correlation with roasting time ($r = -0.144$, $p = 0.567$) or pressing time ($r = -0.024$, $p = 0.926$) and water retention capacity also showed non-significant weak negative correlations for both roasting and pressing. However, swelling capacity was positively and significantly correlated with roasting time ($r = 0.582$, $p = 0.011$) indicating that longer roasting enhances the capacity of flakes to swell during hydration. Pressing time did not show a significant correlation with swelling capacity ($r = -0.328$, $p = 0.184$). This suggests that roasting time is a more decisive factor than pressing time in modifying the functional swelling behavior of flakes likely due to the thermal effects on starch gelatinization and structural changes which increase water absorption and swelling potential. The non-significant correlations with pressing time indicate that mechanical compression during processing may have less impact on features like swelling and

water retention in the final flake product.

Conclusion

A comprehensive understanding of the grain hydration properties, optimisation of process parameters for flaking, evaluation of flakes and quality assessment and functional properties of paddy varieties play a pivotal role in advancing food processing, product innovation, and nutritional enhancement. Assessing parameters such as swelling index, swelling capacity, and water retention capacity in selected cultivars provides critical insights into grain behavior during hydration and thermal processing. This knowledge not only supports the development of value-added products with desirable texture and moisture profiles but also informs the strategic selection of varieties suited to specific consumer preferences and processing technologies. Such evaluations are particularly valuable in designing scalable solutions for FPOs, SHGs, and community nutrition programs, where varietal performance directly influences product quality, shelf stability,

and market acceptance.

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