International Journal of Food and Fermentation Technology
Citation: *Int. J. Food Ferment. Technol.*, **14**(01): 291-301, June 2024
DOI: 10.30954/2277-9396.01.2024.3

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

Research Paper

Effect of Soaking Temperature on the Physical Properties of Paddy (Variety: PS-5)

Alka Singh*, Suresh Chandra, Neelash Chauhan, Jaivir Singh, D.K. Mishra and B.R. Singh

Department of Agricultural Engineering, S.V. Patel University of Agriculture and Technology, Meerut (UP), India

*Corresponding author: singh19alka@gmail.com

Paper No.: 287 **Received:** 11-03-2024 **Revised:** 25-05-2024 **Accepted:** 04-06-2024

ABSTRACT

The engineering properties are important in design and development of processing and handling equipment and storage structures. In the present investigation, some of the engineering properties which are important in storage were determined for the paddy variety (PS-5). The research work was carried out to effect of soaking temperature on physical properties of Paddy (variety PS-5). Then raw paddy was soaked at different temperatures (AT, 40°, 50 °C, 60°C) for 3.5 hr (210 min) by using water bath. Raw paddy and soaked was used to calculate the Length, Width, Thickness, Moisture content, GMD, AMD, Aspect ratio, surface area, sphericity, porosity, volume, Bulk Density, Taped Density, thousand kernel weight. Initial moisture content was found 10.20%.

Keywords: Thickness, Moisture content, Aspect ratio, surface area, sphericity

Paddy is one of mostly cultivated and consumed crop in the world. A complete seed of rice is called paddy and contains one rice kernel. Outer layer of rice shell is called husk. The next layer is called rice bran and the innermost part is called rice kernel. Paddy is the most important and extensively grown food crop in the World. It is the staple food of more than 60 percent of the world population. Rice is mainly produced and consumed in the Asian region. India has the largest area under paddy in the world and ranks second in the production after China. Rice is a good source of proteins, phosphorus and iron. It also contains some amount of calcium. Most of the nutrients and minerals in rice are concentrated in the outer brown layers know as husk and germs. Hence brown rice, a type of rice which only husk has been removed is the most nutritious type of rice. The protein of rice contains glutelin, which is also known as oryzenin. The physical and hydration properties of rice, which are important in the design and selection of storage structures and storage and processing equipment depend on grain moisture content. Therefore, the determination and consideration of properties such as bulk density, true density, angle of internal friction and static coefficient of friction of grain has an important role. Knowing the grain's bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities. They can affect the rate of heat and mass transfer of moisture during the aeration and drying processes. A grain bed with low porosity will have greater resistance to water-vapor escape during the drying process which may lead to the need for higher power to drive the aeration fans.

How to cite this article: Singh, A., Chandra, S., Chauhan, N., Singh, J., Mishra, D.K. and Singh, B.R. (2024). Effect of Soaking Temperature on the Physical Properties of Paddy (Variety: PS-5). *Int. J. Food Ferment. Technol.*, **14**(01): 291-301.

Source of Support: None; **Conflict of Interest:** None

Cereal-grain kernel densities have been of interest in breakage susceptibility and hardness studies (Jouki and Khazaei, 2012).

Engineering properties of grains are most important in many problems associated with the design of processing and handling machines and of the behavior of the product during agricultural processing unit operations such as handling, harvesting, threshing, cleaning, sorting, drying and Storage. Solutions to problems in these processes involve knowledge of the engineering properties of kernel densities are used in breakage susceptibility and hardness studies (Varnamkhasti *et al.* 2007). Physical properties of rice varieties are important factors that have to be considered when designing equipment for handling, conveying, separation, dehusking, drying and storage. The grain weight, diameter, surface area, bulk density, thickness, length and width of rice variety have to be factored into the design and optimal performance of grain threshing machines (Simonyan *et al.* 2007).

Complexity in structure of paddy and variations in physicochemical properties have the practical concerns in processing, handling and storage. Parboiling is a regular process in rice industries which is the pre-milling hydrothermal treatment of the paddy for physico-chemical changes in it. It has other benefits also, such as retention of nutrients, improved milling yield, sterilization, resistance to insect attack and increased shelf-life soaking or hydration is the main step, which has subsequent effects on quality of end product of rice. During hydration process, the time-temperature combination plays a major role; these conditions also change depending on the variety due to its chemical composition and grain type. This knowledge is important in the designing of machinery to harvest and in preparation of processing chain from grain to food.

MATERIALS AND METHODS

Physical properties of raw paddy

Physical properties of paddy like length (L, mm), width (W, mm) and thickness (T, mm) were measured by Vernier caliper for 100 randomly selected grains. Using this data, volume (V, mm^3), geometric mean diameter (Dg, mm), sphericity (Φ), surface area (S, mm^2) and aspect ratio (Ra) of the paddy were calculated as per equations used. Bulk density was estimated from the ratio of mass of paddy grains to volume occupied by bulk grain including volume of inter granular air and grains. True density of the paddy was determined as the ratio of mass of grains to the volume occupied sample and was done employing liquid displacement method. As a liquid, toluene was used instead of water, to prevent absorption or penetration of moisture into the sample matrix. Based on the true and bulk density values, porosity was worked out, by using the following equation. Specific gravity of cultivars was also calculated based on the following formula.

Bulk Density: Bulk density was determined by filling a cylindrical container of 500 ml volume with the grains from a height of 150 mm and then weighing the contents (Garnayak *et al.* 2008). No separate manual compaction of kernels was done. Bulk density was calculated as the ratio of the mass of the kernels to the volume of the container. At each moisture content level, five replications were carried out.

$$\text{Bulk density} = \frac{\text{Mass}}{\text{Volume}} \qquad \ldots(1)$$

True density: The true density defined as the ratio of the mass of paddy grains and the true volume of the grains, was determined using the toluene (C_7H_8) displacement method. The volume of toluene displaced was found by immersing a weighed quantity of paddy grains in the measured volume of toluene (Garnayak *et al.* 2008). Five replications were carried out at each moisture level.

$$\text{True density (g/m}^3\text{)} = \frac{\text{Mass of tapped sample}}{\text{Tapped volume}} \qquad \ldots(2)$$

Porosity: Porosity of paddy grains at various moisture contents was calculated from bulk and true densities using the relationship (Mohesenin, 1986).

$$\text{Porosity } (\varepsilon) = \left[1 - \frac{\rho b}{\rho t}\right] \times 100 \qquad \ldots(3)$$

Where,

ε = Porosity %

b = Bulk density, kg.m^{-3},

t = True density, kg.m^{-3},

Size: The size of the grain was determined by measuring the liner dimension length (L), width (W) and thickness (T) measuring in mm at three levels of moisture content with the help of a digital vernier caliper having the least count of 0.001mm. The average size of the paddy grains was calculated from randomly selected 20 grains samples from each varieties lot having various levels of moisture content from 11.86 to 23.61% d.b. the equivalent diameter (Dp) in mm was calculated through the following expression (Mohesenin, 1986).

$$D_p = \left[4L\left(\frac{W+T}{4}\right)^2\right]^{\frac{1}{3}} \quad \ldots(4)$$

Volume: The grain volume of paddy was determined using different expression as described by (Mohesenin, 1986).

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L\left(W+T\right)^2\right] \quad \ldots(5)$$

Geometric mean diameter: Thegeometric mean diameter (Dg) was calculated by using the relationship (Mohesenin, 1986).

$$D_g = \left[LWT\right]^{(1/3)} \quad \ldots(6)$$

Where,

L = longest intercept (Length),

B = longest intercept to L(Width),

T = longest intercept to L and B (Thickness).

Arithmetic mean Diameter: The arithmetic mean diameter, of the grain was expressed by (Suliman, 1987) using the following relationship:

$$AMD = \frac{L+W+T}{3} \quad \ldots(7)$$

Where,

L = longest intercept (Length)

B = longest intercept normal to Length (Width).

T = longest intercept normal to Length and Width (Thickness).

Thousands kernel weight: Three samples of each crop were taken and their weight determined by an electronic balance with a least count of 0.01 g. Number of grains in each sample was counted and thousand grain weight of each sample (PS-5) was calculated by following relationship (Bala, 2016).

$$\text{Unit kernel weight (g)} = \frac{W_{10000}}{1000} \quad \ldots(8)$$

Where,

W_{1000} = Weight of 1000 kernel of paddy,g

Surface area (A_s): Surface area (As) in mm^2 of paddy grain was found by analogy with a sphere of same geometric mean diameter (Tunde and Akintunde *et al*. 2004).

$$As = \pi D_g^2 \quad \ldots(9)$$

Aspect Ratio: The aspect ratio (Ra) used for classified of paddy shape and it was calculated as (Mohesenin, 1986).

$$Ra = \frac{W}{L} \quad \ldots(10)$$

Sphericity: Shape of paddy can be expressed in the terms of sphericity (Φ). It is defined as the ratio or the surface area of sphere having the same volume as that of the paddy to the surface of the paddy was determined as (Mohesenin, 1986).

$$\Phi = \frac{\left(LWT\right)^{1/3}}{L} \quad \ldots(11)$$

Where,

ϕ = Sphericity,
L = Length of grain, mm,
W = Width of grain, mm, and
T = Thickness of grain, mm.

Determination of moisture content

Initial moisture content: Estimation of moisture content of paddy. The moisture content of paddy samples was estimated by AOAC (2000) method, using a hot air oven at 105°C 5 g of sample was weighed and kept in oven for 2 h. The experiment was continued until a constant weight was achieved, gravimetrically. The amount of moisture in a product is given on the basis of the weight of water present in the product and is usually expressed in percent.

$$\text{Initial Moisture content (\%)} = \frac{W_i - W_f}{W_i} \times 100 \quad \ldots(12)$$

W_i = Initial weight of paddy taken, *g*

W_f = final weight of paddy after oven drying, *g*

Moisture content after pretreatment: Moisture content of sample after pretreatment was computed through mass balance. The following equation was used:

$$m.c'. = \left(1 - \frac{W_d}{W_{ap}}\right) \times 100 \quad \ldots(13)$$

Where,

m.c.' = Moisture content of sample after pretreatment, % (wb)

W_{ap} = Weight of sample after pretreatment, *g*

W_d = Weight of bone-dry material, *g*

W_d was calculated by following formula;

$$W_d = W_{bp}\left(1 - \frac{IMC}{100}\right) \quad \ldots(14)$$

Where,

W_{bp} = Weight of sample before pretreatment, *g*

IMC = Initial moisture content of sample, % (wb)

Moisture content during soaking experiment: Moisture content of the sample during hydration was computed through mass balance. For this purpose, weight of the sample during hydration was recorded at pretreatment time interval. The following formulae were used to calculated the moisture content.

$$M.C. = \frac{W - W_{d'}}{W_{d'}} \times 100 \quad \ldots(15)$$

Where,

M.C. = Moisture content, % (db)

W = Weight of sample at any time, *g*

Wd' = Weight of bone-dry material, *g*

Weight of bone dry of material was calculated as;

$$W_d' = W_i \times \left(\frac{100 - m.c'.}{100}\right) \quad \ldots(16)$$

Where,

W_i = Initial Weight of sample, *g*

m.c.' = Moisture content of sample after pretreatment, % (wb)

Calculation of final weight of the sample: The final weight of each sample was calculated using following equation.

$$W_f = W_d'\left(1 + \frac{FMC}{100}\right) \quad \ldots(17)$$

Where,

W_f= final weight of sample at the end of hydration, *g*

Wd' = weight of bone-dry material taken for drying, *g*

FMC = Final moisture content of sample, % (db)

Color measurement

Color of paddy samples was determined using Hunter Lab and expressed in terms of (L*, a*, b*) L (luminance or brightness), a [red (+), green (-)] and b [yellow (+), blue (-)] values. Values (Dutta and Mahanta, 2012). Since discoloration occurs post parboiling, in this study also color of grains was estimated post hydration.

RESULTS AND DISCUSSION

The research work was conducted in the laboratories developed under the Agro Processing Centreat College of Post Harvest Technology and Food Processing, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. Six variety of paddy were collected from the Seed Processing Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. Paddy variety i.e.,PS-5 was selected for present study. The soaking of paddy was done in October 2022 with varying temperatures i.e. (Ambient, 40°C, 50°C, 60°C) for a constant period of 3.5h (210 min). The physical properties paddy (PS-5) like length, width, Thickness, GMD, AMD, volume, moisture content, surface area, sphericity, aspect ratio, thousand kernel weight, bulk density, true density and porosity were evaluated for fresh as well as soaked paddy and to investigate the effect of soaking on physical properties of paddy.

Physical properties of Raw Paddy

The physical properties of raw paddy (PS-5) were determined as moisture content (10.200) %, Length (11.590) mm, Width (1.890) mm, Thickness (2.110) mm, GMD (3.589) mm, AMD (5.197) mm**,** Volume (46.237) mm^3**,** Surface area (40.461) mm^2, Sphericity (0.319) %, Aspect ratio (5.868) %, Thousand Kernel weight (28.201) g, Bulk density (447.41) g/m, True density (530.33) g/m, Porosity (15.997) % were determined. The score of color values was found as L^*(53.23), a^*(7.62) and b^*(28.46).

Effect of soaking temperature on physical properties of Paddy

Moisture Content of Paddy: The changes in moisture content with varying soaking temperature of paddy (variety: PS-5) is given in Table 1 and graphical representation in Fig. 1.

Table 1: Effect of Soaking Temperature on Moisture content of Paddy (PS-5)

Time (min)	Moisture Content (%)db			
	AT	40°C	50°C	60°C
0	10.20	10.20	10.20	10.20
30	18.50	18.20	19.50	21.50
60	21.50	22.50	24.50	26.20
90	23.00	24.50	26.57	29.50
120	23.80	26.52	28.54	31.52
150	24.50	28.00	29.50	32.55
180	25.00	28.98	29.90	33.51
210	25.42	29.07	30.23	34.12

The moisture content of paddy was increased highest at 60°C soaking temperature and lowest at ambient temperature. Moisture content of paddy varied 10.20 to 25.42 % at ambient temperature, 10.20 to 29.07% at 40⁰C, 10.20 t0 30.23% at 50°C and 10.20 to 34.12% at 60⁰C soaking temperatures. The study concluded that the water absorption by paddy was observed highest at soaking temperature of 60°C. The increasing soaking temperature increased the water absorption capacity of grain. The similar trends were observed in wheat grain (Vengaiah *et al.* 2012) and Kidney bean **(**Chandra and Samsher, 2021).

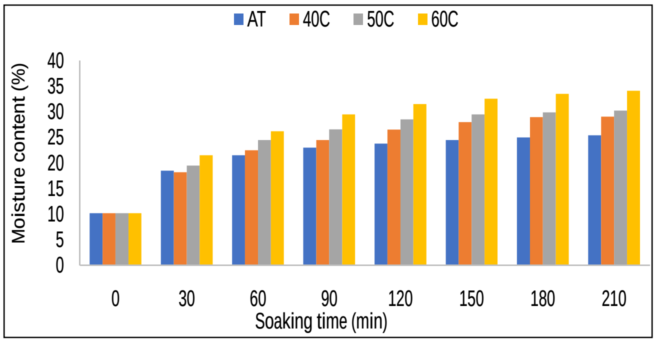

Fig. 1: Effect of Soaking Temperature on Moisture content of Paddy (PS-5)

Thousand kernel weight (g): The change in 1000 kernel weight with varying soaking temperature of paddy (variety: PS-5) is given in Table 2 and graphical representation in Fig. 2. The values of PS-5 range between 28.201-32.205 gm (AT), 28.201-33.917 gm (40°C), 28.201-36.836 (50°C), and 28.201-36.634 gm (60°C) at a time interval of 30 minutes. The present study showed that the highest value of 1000 kernel weight was found to be 34.06 g at (AT) and 32.76 g at 40°c for 150 min (soaking time) while at 50°C and 60°C was found to be 36.83 g 36.63 g for 210 min (soaking time). Therefore, the result revealed that the 1000 kernel weight was increased with increasing soaking time and soaking temperatures. The results concluded that the 1000 kernel weight of paddy increased at different temperatures during the soaking period.

Table 2: Effect of Soaking Temperature on 1000 kernel weight (g) of Paddy Variety (PS-5)

Time (min)	1000 kernel weight (g)			
	AT	40°C	50°C	60°C
0	28.201	28.201	28.201	28.201
30	29.754	28.734	32.640	31.840
60	32.024	33.333	32.568	33.267
90	31.666	32.456	33.317	34.735
120	31.821	33.701	33.753	35.084
150	34.061	32.761	33.436	35.151
180	31.338	32.476	35.514	24.173
210	32.205	33.917	36.836	36.634

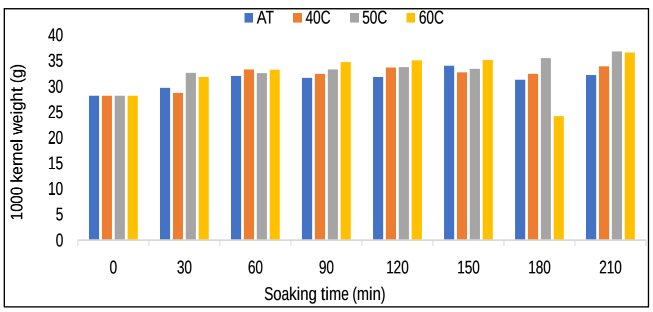

Fig. 2: Effect of Soaking Temperature on 1000 kernel weight (g) of Paddy Variety (PS-5)

Length (mm): The grain length presented in a table and graphical presentation is shown in Fig. 3. In the table 3 at (AT), the grain length varies between (11.590-11.730 mm), (11.590-11.480 mm) at 40°C, (11.590-12.140 mm) at 50°C, and (11.590-9.220 mm) at 60°C. The result shows that at 50°C the grain length has a maximum of 12.140 mm and the lowest value was 9.220 mm at the same time interval (210 min), there was no consistency in grain length. The variation in grain length at different temperatures might be due to the water absorption capacity of paddy grain as temperature increases grain length increases (volumetric expansion), but after a definite time interval (210 min) and temperature (60°C), the grain length decreases. It might be that the grain has attained its saturation moisture content. The length was increases for ADT-43 variety of paddy was gradually increased with increasing the moisture content (Ravi and Venkatachalam, 2014).

Table 3: Effect of Soaking Temperature on unit length (mm) of Paddy (PS-5)

Time (min)	Unit length (mm)			
	AT	40°C	50°C	60°C
0	11.590	11.590	11.590	11.590
30	11.370	11.990	11.980	11.930
60	11.800	12.120	11.200	11.510
90	11.160	11.790	11.210	11.600
120	11.900	11.700	10.840	11.870
150	11.930	13.340	11.730	11.920
180	11.430	12.070	11.750	10.970
210	11.730	11.480	12.140	9.220

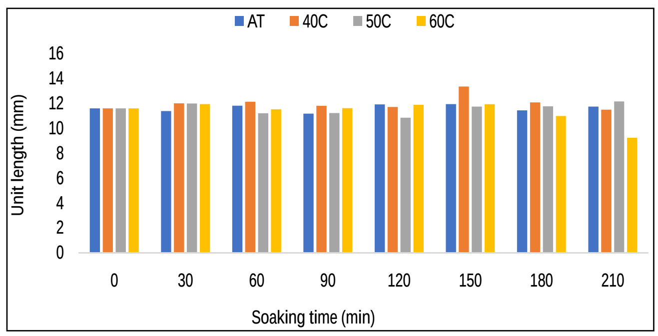

Fig. 3: Effect of Soaking Temperature on unit length (mm) of Paddy (PS-5)

Width (mm): The grain width presented in a table and graphical presentation is shown in Fig 4. In the table4 at ambient temperature, the grain width varies between (1.890-1.860), (1.890-1.990 mm) at 40°C, (1.890-2.210 mm) at 50°C, and (1.890-1.670 mm) at 60°C. The result shows that at 40°C the grain length has a maximum of 2.410 mm and the lowest value was 1.670 mm at the same time interval (210 min), there was no consistency in grain width. The variation in grain width at different temperatures might be due to the water absorption capacity of paddy grain as temperature increases grain width increases (volumetric expansion), but after a definite time interval (210 min) and temperature (60°C), the grain length decreases. It might be that the grain has attained its saturation moisture content Similar results were reported in that an increase in the temperature of the soaking water increased the rate of water absorption and reduced the time for reaching saturation moisture content for paddy (Ejebe, 2019).

Table 4: Effect of Soaking Temperature on unit width (mm) of Paddy (PS-5)

Time (min)	Unit width (mm)			
	AT	**40°C**	**50°C**	**60°C**
0	1.890	1.890	1.890	1.890
30	1.850	1.930	1.970	1.950
60	1.950	1.930	1.860	1.490
90	1.940	1.960	1.780	1.880
120	1.960	1.950	1.850	2.000
150	1.930	2.410	2.020	2.030
180	1.890	1.950	2.060	2.030
210	1.860	1.990	2.210	1.670

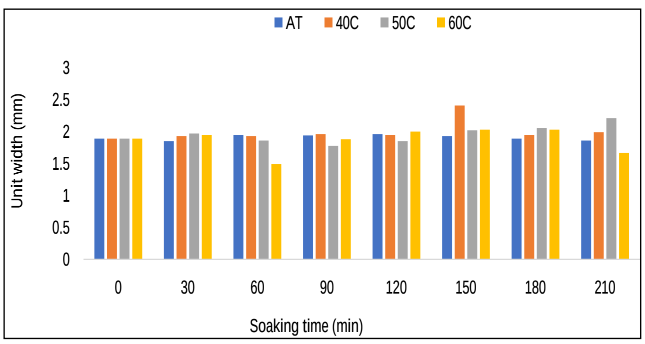

Fig. 4: Effect of Soaking Temperature on unit width (mm) of Paddy (PS-5)

Thickness (mm): The grain thickness presented in a table and graphical presentation is shown in Fig. 5. In the table 5 at ambient temperature, the grain thicknesses vary between (2.110-2.360), (2.110-2.200 mm) at 40°C, (2.110-2.250 mm) at 50°C, and (2.110-2.090 mm) at 60°C. The result shows that at ambient the grain thickness has a maximum of 2.360 mm and the lowest value was 2.090 mm at the same time interval (210 min), there was no consistency in grain thickness. The variation in grain width at different temperatures might be due to the water absorption capacity of paddy grain as temperature increases grain width increases (volumetric expansion), but after a definite time interval (210 min) and temperature (60°C), the grain width decreases. It might be that the grain has attained its saturation moisture content. Similar results were reported in that an increase in the temperature of the soaking water increased the rate of water absorption and reduced the time for reaching saturation moisture content for paddy (Ejebe *et al.* 2019).

Table 5: Effect of Soaking Temperature on unit thickness (mm) of Paddy (PS-5)

Time (min)	Unit thickness (mm)			
	AT	**40°C**	**50°C**	**60°C**
0	2.110	2.110	2.110	2.110
30	2.090	2.240	2.220	2.210
60	2.190	2.180	2.800	2.200
90	2.210	2.220	2.160	2.290
120	2.270	2.190	2.230	2.290
150	2.680	2.710	2.330	2.260
180	2.170	2.190	2.310	2.290
210	2.360	2.200	2.250	2.090

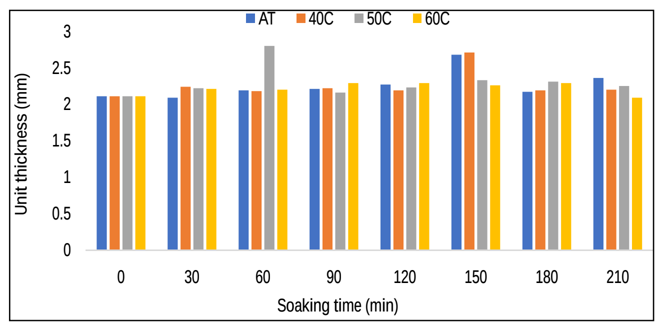

Fig. 5: Effect of Soaking Temperature on unit thickness (mm) of Paddy (PS-5)

Arithmetic mean diameter (AMD): Arithmetic mean diameter (AMD) of the raw paddy (PS-5) is calculated as 5.197 mm. The AMD of PS-5 soaked at room temperature varied from (5.197) to (5.317) mm at 40°C (5.197) to (5.223), at 50°C (5.197 to 5.533) and at 60°C (5.197 to 4.327) with the soaking time up to 210 min. The AMD was calculated at 50°C soaking temperature and minimum at 60°C. The increasing soaking temperature for PS-5 was found invariable it was soaked up to 210 min, from table 6, represent the best AMD result found at 50°C temperature of soaking up to 210 min in water, followed by room temperature, higher temperature of soaking above 50°C temperature was not observed best for PS-5 variety of paddy.

Table 6: Effect of Soaking Temperature on AMD (mm) of Paddy (PS-5)

Time (min)	AMD (mm)			
	AT	40°C	50°C	60°C
0	5.197	5.197	5.197	5.197
30	5.103	5.387	5.390	5.363
60	5.313	5.410	5.287	5.067
90	5.103	5.323	5.050	5.257
120	5.377	5.280	4.973	5.387
150	5.513	6.153	5.360	5.403
180	5.163	5.403	5.373	5.097
210	5.317	5.223	5.533	4.327

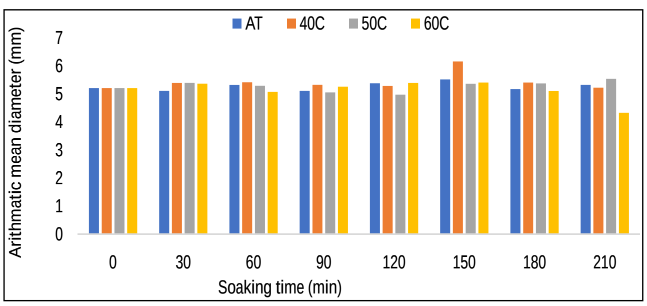

Fig. 6: Effect of Soaking Temperature on AMD (mm) of Paddy (PS-5)

Geometric mean diameter (GMD): Geometric mean diameter (GMD) of the raw paddy (PS-5) is calculated as 3.589 mm. The AMD of PS-5 soaked at room temperature varied from 3.589 to mm at 40°C (3.589) to (3.690), at 50°C (3.589) to (3.923) and at 60°C (3.589) to (3.589) to (3.181) with the soaking time up to 210 min. The GMD was calculated at 50⁰C soaking temperature and minimum at 60°C. The increasing soaking temperature for PS-5 was found invariable it was soaked up to 210 min, from table 7, represent the best GMD result found at 50°C temperature of soaking up to 210 min in water, followed by room temperature, higher temperature of soaking above 50°C temperature was not observed best for PS-5 variety of paddy.

Table 7: Effect of Soaking Temperature on GMD (mm) of Paddy Variety (PS-5)

Time (min)	GMD (mm)			
	AT	40°C	50°C	60°C
0	3.589	3.589	3.589	3.589
30	3.529	3.729	3.742	3.718
60	3.694	3.708	3.878	3.354
90	3.630	3.716	3.506	3.683
120	3.755	3.683	3.550	3.788
150	3.952	4.433	3.808	3.796
180	3.606	3.722	3.824	3.708
210	3.720	3.690	3.923	3.181

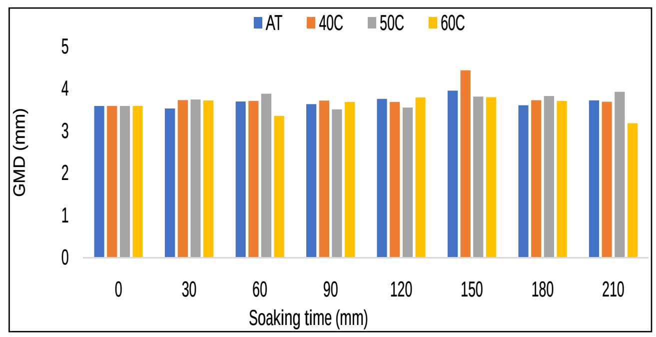

Fig. 7: Effect of Soaking Temperature on GMD (mm) of Paddy Variety (PS-5)

Volume: The grain Volume presented in a table and graphical presentation is shown in Fig 8. The volume of the paddy was calculated for raw samples as well as samples soaked at different temperatures. The value of volume of paddy (PS-5) varies between (43.89-58.45 mm^3), (46.23-82.31 mm^3) at 40°C, (42.75-53.33 mm^3) at 50°C, and (29.51-53.47 mm^3) at 60˚C which was less compared to other researchers. Similar results were also obtained by (Balbinoti *et al.* 2018). This is may be due to the presence of husk which acts as barrier for the rice expansion. According to (Saikrishna *et al.* 2018), ageing of rice influences the volume expansion of rice when it is cooked or soaked and also freshly harvested rice shows low volume expansion compared to aged rice (Aruva *et al.* 2019).

Table 8: Effect of Soaking Temperature on Volume (mm^3) of 1000 kernel Paddy (PS-5)

Time (min)	Volume (mm^3)			
	AT	40°C	50°C	60°C
0	46.237	46.237	46.237	46.237
30	43.890	51.673	46.237	51.156
60	49.966	51.514	52.042	39.679
90	45.987	50.587	53.335	48.955
120	52.156	49.315	42.764	53.064
150	58.452	82.313	42.755	53.475
180	46.189	51.743	53.152	47.527
210	50.513	48.770	50.229	29.511

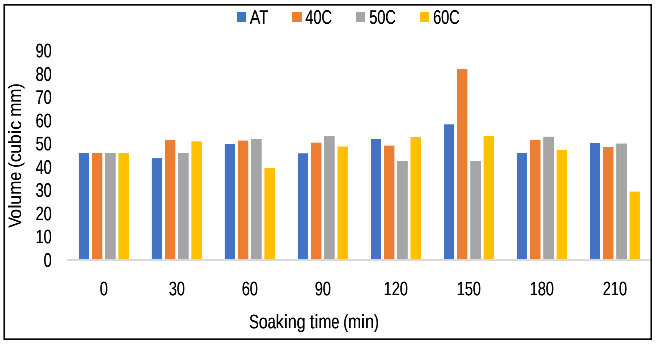

Fig. 8: Effect of Soaking Temperature on Volume (mm^3) of 1000 kernel Paddy (PS-5)

Surface area (mm^2): The surface area of the paddy grain was calculated by using the equation of surface area. As seen from the table 9, the value of surface area of the grain increased with increase in soaking time and moisture content. The variation of the surface area of paddy PS-5 grain moisture content is show in Fig. 9.

Table 9: Effect of Soaking Temperature on Surface area (mm^2) of 1000 kernel Paddy (PS-5)

Time (min)	Surface area (mm^2)			
	AT	40°C	50°C	60°C
0	40.461	40.461	40.461	40.461
30	39.132	43.675	43.988	43.437
60	42.860	43.201	47.251	35.341
90	41.405	43.374	38.619	42.604
120	44.296	42.618	39.581	44.296
150	49.057	61.742	45.550	49.057
180	40.844	43.512	45.937	43.202
210	43.481	42.785	48.344	31.784

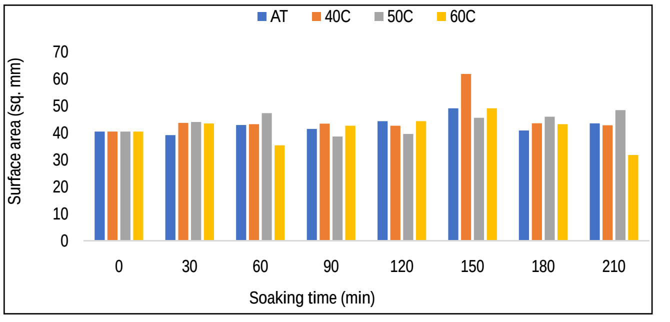

Fig. 9: Effect of Soaking Temperature on Surface area (mm^2) of 1000 kernel Paddy (PS-5)

Sphericity: The value of sphericity was calculated individually by using the data on GMD and the major axis of the grain and the result obtained are presented in Fig. 10.

Table 10: Effect of Soaking Temperature on Sphericity of Paddy (PS-5)

Time (min)	Sphericity			
	AT	40°C	50°C	60°C
0	0.319	0.319	0.319	0.319
30	0.326	0.311	0.312	0.325
60	0.313	0.306	0.310	0.291
90	0.325	0.318	0.313	0.317
120	0.336	0.315	0.327	0.319
150	0.331	0.332	0.325	0.318
180	0.315	0.310	0.325	0.337
210	0.317	0.321	0.328	0.345

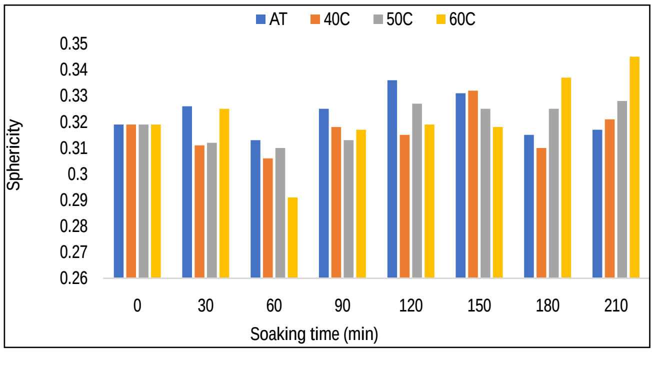

Fig. 10: Effect of Soaking Temperature on Sphericity of Paddy (PS-5)

The sphericity value ranges from 0.345-0.319 at ambient to 60°C during the different time interval.

The maximum value of sphericity found at 60°C (0.345) at 210 min time interval while the lowest value found at 40°C (0.306) at 60 min time interval. The result indicates that sphericity depend upon the physical properties (length, width and thickness) of the grain if the value of physical properties increases then the sphericity value also increases at different temperature at different time interval. Similar result was reported in (Shittu *et al.* 2009).

Aspect ratio: The values of aspect ratio shown in table. And graphical representation was shown in Fig. 11. The values of aspect ratio ranges from 1.002-6.298 at different temperature and time interval. The result indicates that the aspect ratio increases at ambient temperature during the 0-210 min time interval. The highest value found 6.306 (210 min) at ambient temperature on the other side the lowest value was 1.002 (60 min) at 60°C.

Table 11: Effect of Soaking Temperature on Aspect Ratio of Paddy (PS-5)

Time (min)	Aspect Ratio			
	AT	40°C	50°C	60°C
0	5.868	5.868	5.868	5.868
30	5.854	6.212	6.081	6.108
60	6.051	6.247	6.146	1.002
90	5.753	6.015	6.298	6.170
120	6.071	6.166	5.859	5.935
150	6.181	5.535	5.807	5.872
180	6.048	6.096	5.709	5.458
210	6.306	5.769	1.896	5.521

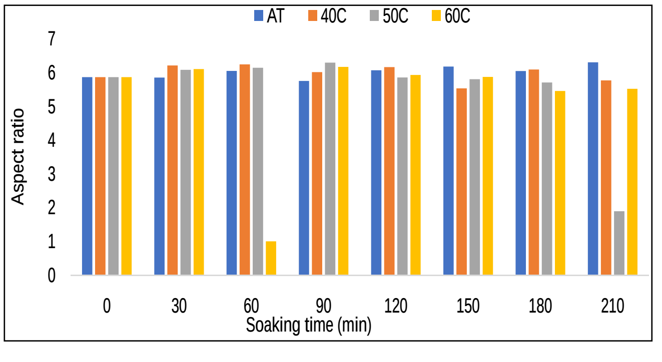

Fig. 11: Effect of Soaking Temperature on Aspect Ratio of Paddy (PS-5)

The result demonstrate that the aspect ratio of paddy increases as the soaking temperature increase. Similar result reported in Aruva *et al.* (2019).

CONCLUSION

The study was carried out the effect soaking temperature on the physical properties of paddy variety PS-5. The physical properties were calculated like Length, Width, Thickness, Moisture content, GMD, AMD, Aspect ratio, surface area, sphericity, porosity, volume, Bulk Density, Taped Density, thousand kernel weight and color value (L^*, a^*, b^*). The study showed that the highest value of 1000 kernel weight was found to be 34.06 g at (AT) and 32.76 g at 40°C for 150 min (soaking time) while at 50°C and 60°C was found to be 36.83 g 36.63 g for 210 min (soaking time). The maximum value of sphericity found at 60°C (0.345) at 210 min time interval while the lowest value found at 40°C (0.306) at 60 min time interval. The investigation into the properties of paddy gives rise to a number of conclusions. This paper concludes with information on engineering properties of PS-5 variety which may be useful for designing much of the equipment used for rice processing. The all grain of paddy PS-5 were of medium size while their kernel width correlated most significantly with the volume and surface area of the grains, which are important for drying, aeration, heating and cooling. Moisture content of paddy is one of the most important factors influence the maintenance of paddy quality. From the result obtained that all the physical properties of paddy are dependent on the moisture content.

ACKNOWLEDGEMENTS

We empathetically extend my heartfelt gratitude, appreciation and venerable thanks to the RKVY, funded Project "Establishment of Agro-Processing Centre (CoPHT&FP) and Principal Investigator to provide the experimental facilities for the entire study is acknowledged.

REFERENCES

Aruva, S., Dutta, S. and Moses, J.A. 2019. Comparative study on hydration kinetics of selected Indian paddy varieties. *International Journal of Chemical Studies*, **7**(4): 738-743.

Bala, B.K. 2016. Drying and storage of cereal grains. John Wiley and Sons., Canada.

Balbinoti, T.C.V., Jorge. L.M., de M. and Jorge, R.M.M. 2018. Modeling the hydration step of the rice (*Oryza sativa*) parboiling process. *Journal of Food Engineering*, **216**: 81-89.

Chandra, S. and Samsher. 2021. Normal water soaking depended physical properties of white speckled kidney beans (*Phaseolus vulgaris*). *In:* Chandra, S., Samsher; Goyal, S.K. and Kumari, D., Engineering Properties of Agricultural Produce. CRC Press New York and NIPA India, pp. 23-30.

Dutta, H. and Mahanta, C.L. 2012. Effect of hydrothermal treatment varying in time and pressure on the properties of parboiled rice with different amylose content. *Food Research International*, **49**(2): 655-663.

Ejebe, C., Kwofie, E.M. and Ngadi, M. 2019. Hydration Characteristics of Selected Varieties of Paddy Rice from Nigeria. *Advances in Chemical Engineering and Science*, **9**: 65-75.

Garnayak, D.K., Pradhan, R.C., Naik, S.N. and Bhatnagar, N. 2008. Moisture-dependent physical properties of Jatropha seed (*Jatrophacurcas* L.). *Indian J. Crops Products*, **27**: 123-129.

Jouki, M. and Khazaei, N. 2012. Some Physical Properties of Rice Seed (*Oriza sativa*). *IIOAB Journal*, **3**(4): 15-18.

Mohsenin, N.N. 1986. Physical Properties of Plant and Animal Materials (2Edn.). Gordon and Breach Science Publishers, New York.

Ravi, P. and Venkatachalam, T. 2014. Important engineering properties of paddy. *Scientific Journal Agriculture Engineering*, **34**(4): 73-83.

Saikrishna, A., Sayantani, D., Vijayalakshmi, S., Moses, J.A. and Krishnan, C. 2018. Ageing of rice: A review. *International Journal of Chemical Studies Journal of Cereal Science*, **81**: 161-170.

Shittu, T.A., Aminu, R.A. and Abulude, E.O. 2009. Functional effects of Xanthan gum on composite cassava–wheat dough and bread. *Food Hydrocolloid*, **23**: 2254–2260.

Simonyan, K.J., El-Okene, A.M. and Yiljep, Y.D. 2007. Some physical properties of samaru sorghum 17 grains. *Agricultural Engineering International*, **9**: 1-15.

Suliman, S.N. 1987. Prediction of energy components for two rubber rolls paddy husker. *Misr J. Ag. Eng.*, **4**(1): 13-24.

Tunde-Akintunde, T.Y. and Akintunde, B.O. 2004. Some physical properties of sesame seed. *Bio-systems Engg.*, **88**: 127–129.

Varnamkhasti, G.M., Mobli, H., Jafari, A., Keyhani, A.R. Heidari Soltanabadi, M., Rafiee, S. and Kheiralipour, K. 2007. Some physical properties of paddy. *Int. J. Agri. Biol.*, **9**(5): 763- 766.