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Effect on physical, chemical and functional characteristics during transformation of paddy to flaked rice: (POHA)

Rahul Dahare, Bhupendra Sahu and S Patel

Abstract
The present study was undertaken to study effect of dimensional, gravimetric, frictional, proximate, functional and chemical characteristics during transformation of paddy (Chhattisgarh Zinc Rice) to its process product flaked rice (*Poha*). The major change in Length from paddy to flaked rice were found to be 9.50 mm to 11.36 mm for thick and 9.50 mm to 16.67 mm for thin flaked rice. For change in Width from paddy to flaked rice were found to be 2.34 mm to 3.75 mm for thick and 2.34 mm to 8.37 mm for thin flaked rice. Similarly, change in Thickness from paddy to flaked rice were found to be 1.91 mm to 0.78 mm of thick and 1.91 mm to 0.24 mm for thin flaked rice. the change in True density from paddy were found to be 1114.55 to 1266.05 kg/m^3 for thick and 1057.89 kg/m^3 for thin flaked rice. And, change in Bulk density from paddy were found to be 578.99 to 435.80 kg/m^3 for thick and 226.70 kg/m^3 of thin sized flaked rice. In the proximate composition major change in Fat content form paddy were found to be 3.58 to 0.92 % for thick and 1.03 % for thin flaked rice. The change in Fiber content from paddy were found to be 3.73 to 2.47 % for thick and 2.00 % for thin flaked rice. In the chemical properties major change in Water Absorbing Index (WAI) from paddy were found to be 2.49 to 6.62 g/g for thick and 5.10 g/g for thin flaked rice and for Water solubility index (WSI) from paddy were found to be 4.02 to 6.29 % for thick and 6.66 % for thin flaked rice.

Keywords: paddy, flaked rice, flatten rice, beaten rice, poha, chiwada

1. Introduction

The grain, called rice (*Oryza sativa* L.) for more than 8000 years, has been the companion of human kind. It is the most important food commodity in Asia, particularly in South and South-East Asia, where more than 90 per cent of rice is produced and consumed. Paddy (*Oryza sativa L.*) is one of the most important staple food crops which is a major source of nutrients in many parts of the world. Paddy is second largest major cereal crop a member of grass family (Graminaceae), which produces starchy seeds. Rice is used as an important staple food by the people in many parts of the world after wheat. Rice is used as a source of nourishment for more than half of the world's population, thus, making it as second most important cereal grain.

Rice contributes about 60–70% of total calories and one-third of daily protein requirement, not only as a dietary staple but also as a convenience food in the form of expanded (puffed) rice, as breakfast cereal, snack foods, multigrain flakes, puffed, popped, flaked, and extruded products. As staple food it plays an important role in the economy of India hence occupies a central position in agricultural policy making (Dangwal *et al*., 2011) [5] and used as an important source for number of industrial products like whole rice, rice starch, rice bran oil, flaked rice, puffed rice and rice husk etc.

Rice flakes are prepared from paddy. It is also popularly known as "*Poha*". It is a fast moving consumer item and generally eaten as breakfast item. It can be fried with spices and chilly to make hot and tasty food item or milk or curd is mixed with it and then eaten. It is also used in large quantities for making '*Chevda*' and many caterers use it for thickness of gravy. Since it is made from paddy, it is easily digestible. Most of its preparations can be made at a short notice and hence bulk of the households stores it on regular basis. With proper storage, its shelf life is 2-3 months. This is a common product and can be produced anywhere in the country.

Flaked rice is a thin crispy snack. It is mainly used as Breakfast cereal. It has high content of fibre and calorific value. It can easily be soaked in cold or hot water. Flaked rice sometimes known as pounded rice is most commonly sold as *poha* or *pawa*.

The flakes are very easy to cook and can make a meal in minutes. Fine flaked rice is good for making a snack. Cleaned rice flakes can be fried quickly and then mixed with fried chillies, nuts, lentils and seasoned with salt and sugar.

Flattened rice can be eaten raw by immersing it in plain water or milk, with salt and sugar to taste, or lightly fried in oil with nuts, raisins, cardamoms, and other spices. The lightly fried variety is a standard breakfast in Malwa region (surrounding Ujjain and Indore) of Madhya Pradesh. It can be reconstituted with hot water to make a porridge or paste, depending on the proportion of water added. In villages, particularly in Chhattisgarh, flattened rice is also eaten raw by mixing with jaggery. In Maharashtra, *Pohe* is cooked with lightly fried mustard seeds, turmeric, green chillies, fine chopped onions and then moistened *pohe* is added to the spicy mix and steamed for a few minutes. *Flattened rice* can be viewed as a convenience food and is very similar to bread in usage.

Table 1: Nomenclature

List of symbols			
L	Length	P_t	True density
B	Breadth	P_b	Bulk density
T	Thickness	P	Porosity
D_g	Geometric mean diameter	θ	Angle of repose
R_a	Aspect ratio	μ	Static coefficient of friction
S	Sphericity		

2. Material and method

2.1 Physical properties

The dimensional characteristics of the material are called size. To determine the average size of the nut, a sample of 100 randomly selected grains were used. Their three principal dimensions, length (L), width (W) and thickness (T) were measured using a digital vernier calliper having the least count of 0.01 mm. The geometric mean diameter, D_g of the particle is also called as the "equivalent diameter". The D_g of the paddy grains was calculated using the following relationship (1) (Mohsenin, 1980) [12].

$$D_g = (LWT)^{\frac{1}{3}} \quad \ldots..1$$

Spherecity is defined as the ratio of surface area of sphere having same volume as that of the seed. Spherecity of the grain were determined by using following equation (2). Aspect ratio is the ratio of width to length of grains, it is denoted by terms of R_a. Aspect ratio of the grain were determined by using following equation (3). Volume, Surface Area and L/B ratio were determined by following relationships.

$$\varphi = \frac{(LWT)^{1/3}}{L} \quad \ldots..2$$

$$(R_a) = \frac{\text{Width (mm)}}{\text{Length (mm)}} \times 100 \quad \ldots..3$$

$$V = \frac{\pi(LWT)}{6} = \frac{\pi D_g^3}{6} \quad \ldots.4$$

$$S = \pi D_g^2 \quad \ldots..5$$

$$\frac{L}{B}\ \text{ratio} = \frac{\text{Length (mm)}}{\text{Width (mm)}} \quad \ldots..6$$

2.2 Bulk density, true density and porosity

The bulk density is the ratio of the mass of a sample of grains to its total volume. The bulk density was determined by filling a measuring cylinder of known volume (150 ml) with each sample. The initial weight of the cylinder was determined using the electronic balance (M_1). The top of the container was gently leveled after filling it with no additional manual compaction was done, the cylinder and the sample was weighted. The bulk weight (M_2) was recorded. The true density (ρ_t) is defined as the ratio of the mass of a sample of a grain or seed to the solid volume occupied by the sample. The true density of the paddy grains was determined by the toluene (C_7H_8) displacement method (Mohsenin, 1978) [13] in order to avoid water absorption by the sample. 5 gram of randomly selected paddy grains were weighted separated and dropped into graduated measuring cylinder having an accuracy of 0.1 ml, containing 25 ml of toluene in 100 ml measuring cylinder. The net volumetric toluene displacement by paddy grains were noted and recorded. Porosity of the bulk sample is the ratio of the volume of internal pores within the paddy grains to its bulk volume. It was calculated as the ratio of the difference in the true density and bulk density to the true density and expressed in percentage (Mohsenin, 1980) [12].

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad \ldots..7$$

2.3 frictional properties of samples

2.3.1 Angle of repose

The angle of repose is the angle with the horizontal at which the material will stand when pile. This was determined by the method suggested by waziri and mettal (1983) [17]. The grain was heaped over a circular disc of 50 mm diameter by allowing them to fall from a height of 150 mm until the maximum height was reached. The height was replicated ten times and reading were recorded. The angle of repose was determined by using following relationship.

$$\theta_f = \tan^{-1}\left[\frac{2H}{D}\right] \quad \ldots..8$$

2.3.2 Static coefficient of friction

The static coefficient of friction of paddy grains of different varieties was measured. The static coefficient of friction of paddy grains were determined on 3 different structural materials, namely, plywood, mild steel sheet and glass. The experimental apparatus used in the coefficient of static friction studies of a frictionless pulley on a frame, an open-ended rectangular metallic box (8x8x4 cm) to contain the sample, loading pan and test surfaces.

The grains are filled in a metallic box which is place on a table. A flat plate of the material chosen for friction test is taken and allowed to rest on the surface of the seeds filled box. A known weight is placed over the plate to exert normal force, N over the surface of the seeds in contact with the surface of the plate. Weights were then added to the loading

pan until the container began to slide. The weight of the seeds and the added weights comprise the normal force and frictional force, respectively. The static coefficient of friction was calculated from following equation (Dabhi and Dhamsaniya, 2010) [4].

$$\mu_s = \frac{F}{N} \quad \ldots 9$$

Fig 1: Raw rice and process product of Chhattisgarh Zinc Rice paddy variety

2.4 Functional properties

2.4.1 Water absorbing index (WAI) and water solubility index (WSI)

One gram sample taken in centrifuge tube was added with 10 ml distilled water and agitated for 30 min followed by its centrifugation at 3000 rpm for 25 min. The decanted centrifuged tube with settled gel at the base was weighed and used in calculation of WAI (Eq. (8)). The supernatant obtained during WAI estimation was used to determine WSI by decanting it into a pre weighed evaporating dish whose final weight after oven drying at 103ºC was recorded and used in the calculation of WSI by using Eq. (9) (Stojceska *et al.*, 2008) [16], (Kumar *et. al.*, 2016) [9].

$$\text{WAI (g/g)} = \frac{\text{Weight of gel}}{\text{Dry weight of sample}} \quad \ldots 10$$

$$\text{WSI (\%)} = \frac{\text{Weight of dry solid in supernatant}}{\text{Dry weight of sample}} \quad \ldots 11$$

2.4.2 Swelling power

The swelling power of rice flour sample was determined by measuring water uptake of sample (Duangrutai Thumrongchote, 2012) [6]. The 500 mg of rice flour was weighted into centrifuge tube and 15 ml of distilled water was added. The suspension was heated in water bath at 80ºC for 30 min. and then centrifuge at 4000 rpm for 20 min. the supernatant was carefully poured into aluminum dish (of known weight) before drying at 105ºC to constant weight and weighing. The sediment was collected and weighed. The swelling power was calculated by using following equation

$$\text{Swelling Power (g/g)} = \frac{\text{Wws}}{\text{Wf} - \text{Wt}} \quad \ldots 12$$

2.5. Chemical properties

2.5.1 Protein content

Nitrogen (N_2 %) of brown rice samples was estimated by using auto Kjeldahl equipment (Kel plus, pelican system, India). Digestion of brown rice (0.5 g sample) was carried out in the auto Kjeldahl equipment at 420ºC for 2.30 hours. The digested sample obtained was distilled with 40% NaOH (sodium hydroxide) and 4% boric acid. The vapor of ammonia obtained after distillation was collected in boric acid (distillation time approximately 7 min.) and then titrated against 0.1 N HCL (hydrochloric acid). The percentage OF N_2 of brown rice sample was calculated by using the following equation (Ranganna, 1995) [14].

$$\text{Nitrogen (\%)} = \frac{14.01 \times (\text{SR} - \text{BR}) \times 0.1 \times 100}{1000 \times \text{Ws}} \quad \ldots 13$$

$$\text{Protein (\%)} = \text{N} \times 6.25 \quad \ldots 14$$

2.5.2 Fat content

Crude fat was determined by using the soxlet apparatus (AOCC, 1995) [2]. Oven dry beaker and sample at 100ºC for half hours. Keep them in desiccators to avoid moisture content gain from the atmospheres. Weight the beakers and note the reading as initial weight. Carefully weight 5 gm of sample flour and keep in cellulose thimble. The thimble was then place in a beaker and beaker is filled with petroleum ether (boiling point 40-60ºC) about 80 ml of beaker. Then beaker is now place in soxlet apparatus with thimble for 2 h at 90ºC. the ether was then removed by evaporation and the beaker with residue in an oven at 105ºC for 30 min., cooled in desiccators and weight. The percentage of oil was calculated by using following equation

$$\text{Fat content (\%)} = \frac{\text{W2} - \text{W1}}{\text{W}} \times 100 \quad \ldots 15$$

2.5.3 Ash content

Ash content was determined according to (AOCC, 1984) [1] procedure. 1 g of sample was taken in a silica crucible and weighted. It was made to ash in a muffle furnace at 600ºC for 4 hours. The crucible was cooled in the desiccators and weighted, and the value of ash content was calculated by using the following equation

$$\text{Ash content (\%)} = \frac{\text{W2} - \text{W1}}{\text{W}} \times 100 \quad \ldots 16$$

2.5.4 Fiber content

Crude fiber was determined by using the fibra plus apparatus (Sadasivam and Manickam, 2005) [15]**.** Oven dry crucible and sample at 100ºC for half hours. Keep them in desiccators to avoid moisture content gain from the atmospheres. Weight the

crucibles and note the reading as initial weight W. Carefully weight 2 gm of sample grind flour and keep in crucible. The crucible was then place in a fibra plus apparatus. And after that, the 1.25 % sulfuric acid (H_2SO_4) is filled from top of the apparatus up to the 150 ml of crucible. And sample is boiled in apparatus at 400ºC for 40 minutes. After completion the acid wash drain the acid and wash the sample twice and thrice with distilled water. During drainage ensure that the knob is in vaccume mode. After acid wash similar process is done. The 1.25 % NaOH (sodium hydroxide) is filled from top of the apparatus up to the 150 ml of crucible. And sample is boiled in apparatus at again 400ºC for 40 minutes. After completion the acid wash drain the acid and wash the sample twice and thrice with distilled water. During drainage ensure that the knob is in vaccume mode. After alkali wash take out crucibles and dry them in a hot air oven until the crucible are free from moisture. Cooled in desiccators. Weight the crucible and record the reading as W1. Place all the crucibles in muffle furnace at 600ºC for ashing. Cool down the hot crucible after ashing to room temperature using a desiccators. Now weight the crucible and record the reading as W2. The fiber content of sample is calculated by using following equation.

$$\text{Fiber content } (\%) = \frac{W1 - W2}{W} \times 100 \quad \ldots..16$$

2.6 Statistical analysis

All experiment were replicated and standard deviation have been reported, CRD and factorial CRD analysis test was carried out to ascertain the variation between varieties for the respective attributes monitored.

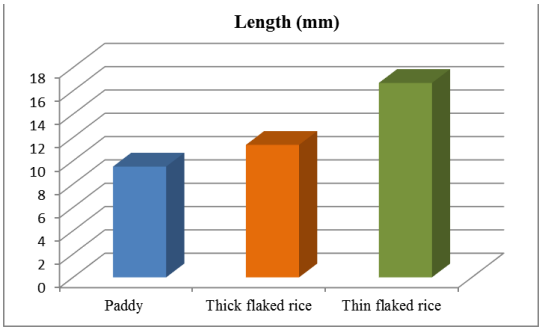
3. Result and discussion

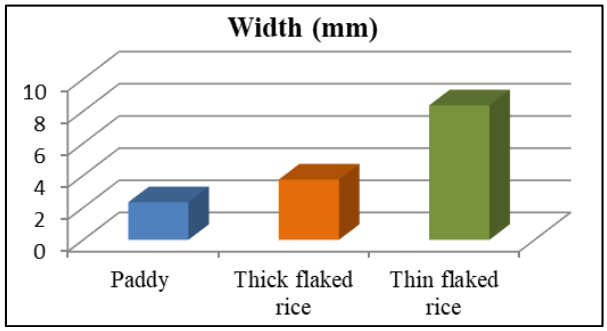
3.1 Physical properties

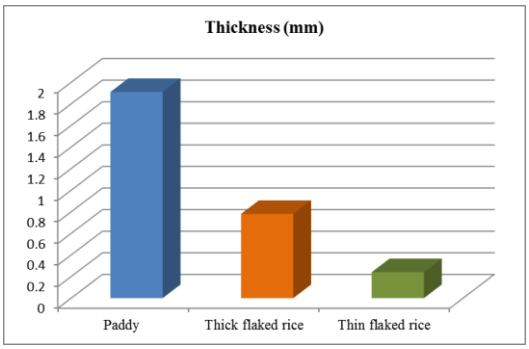
The change in dimensional properties at different levels of processing is eminent as shown in table 1. For thick sized flaked rice, the length, width and thickness varied from 10.34 to 12.38 mm, 3.10 to 4.40 mm and 0.57 to 1.00 mm respectively for Chhattisgarh Zinc Rice paddy variety. And similarly for thin sized flaked rice the length, width and thickness varied from 12.84 to 20.50 mm, 6.08 to 10.67 mm and 0.18 to 0.30 mm respectively for Chhattisgarh Zinc Rice paddy variety, as compare to the length, width and thickness of raw rice 9.50 mm, 2.34 mm and 1.91 mm respectively. The increase in length, width was significant at $p \leq 0.05\%$ during processing of rough rice to flaked rice whereas its thickness followed the opposite trend with dimension decreasing from 1.91 to 0.24 mm. Rice grain flattened during double flaking process increased its length at the expense of thickness and yielded a product with higher major dimensions and lower minor dimension. Geometric mean diameter of Chhattisgarh Zinc Rice ranged from 2.97 to 3.26 mm for thick sized flaked rice and 2.99 to 3.80 mm for thin sized flaked rice respectively. Similarly Aspect ratio of Chhattisgarh Zinc Rice ranged from 23.42 to 38.63 % for thick sized flaked rice and 28.44 to 57.13 % for thin sized flaked rice respectively.

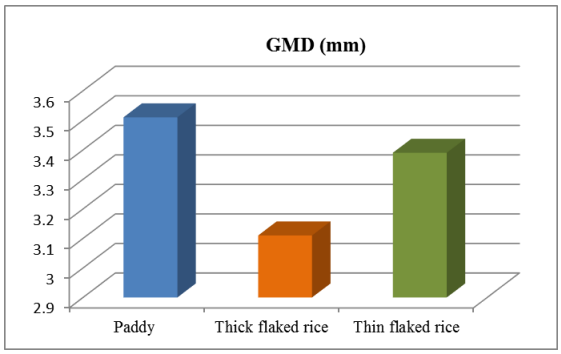
Table 2: Chhattisgarh zinc rice paddy variety

Parameter	Replication	Chhattisgarh Zinc Rice paddy variety		
		Paddy	Thick flaked rice	Thin flaked rice
Length (mm)	100	9.50 ± 0.40	11.36 ± 0.84	16.67 ± 2.80
Width (mm)	100	2.34 ± 0.16	3.75 ± 0.32	8.37 ± 1.60
Thickness (mm)	100	1.91 ± 0.09	0.78 ± 0.12	0.24 ± 0.04
GMD (mm)	100	3.51 ± 0.11	3.11 ± 0.17	3.39 ± 0.23
Aspect ratio (%)	100	26.11 ± 2.28	31.02 ± 3.43	42.78 ± 12.55
Sphericity (%)	100	38.37 ±1.61	26.07 ± 1.88	17.99 ± 2.44
Surface area ($mm^{2)}$	100	39.29 ± 2.43	34.06 ± 3.68	36.80 ± 5.01
Volume (mm^3)	100	24.07 ± 2.25	32.62 ± 4.89	185.27 ±69.45
L/B ratio	100	4.21 ± 0.31	3.07 ± 0.34	2.03 ± 0.57









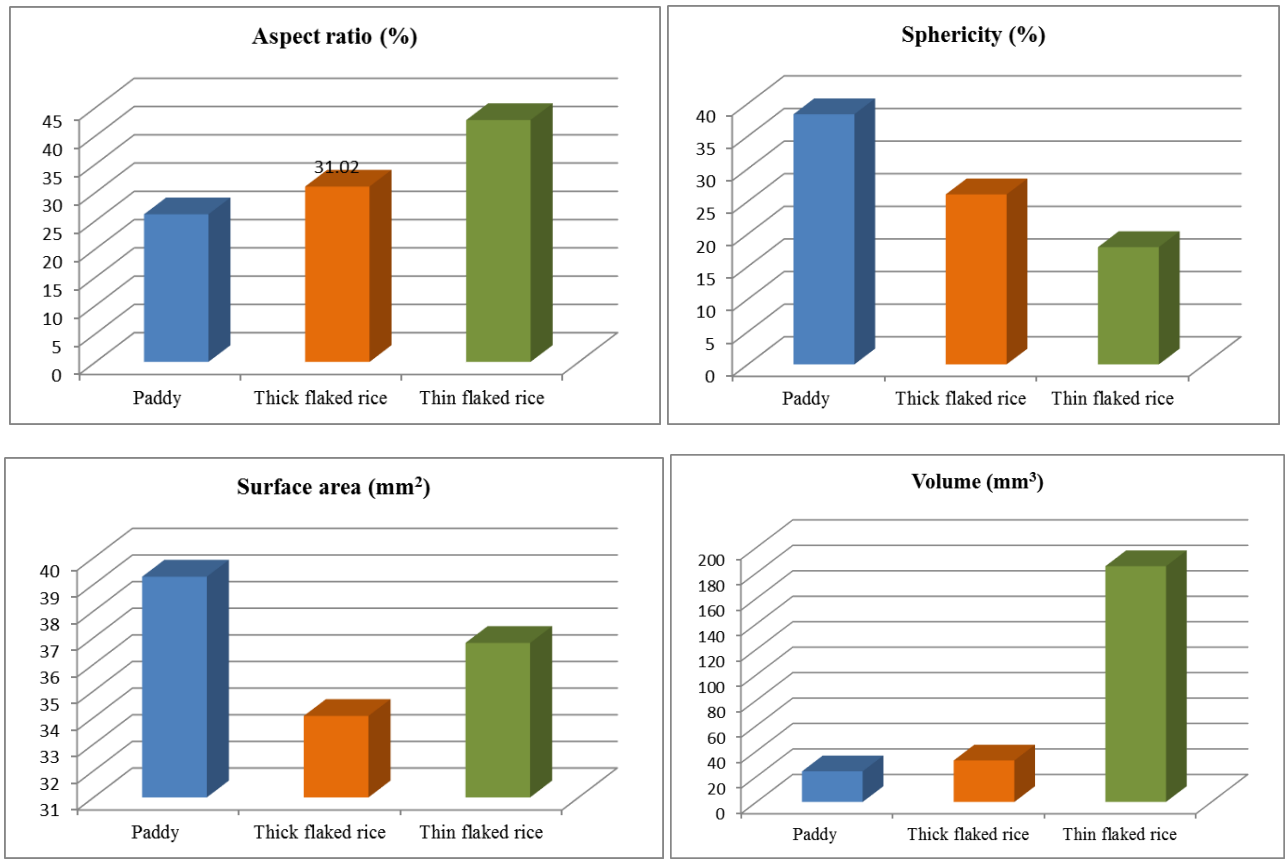


Fig 2: Effect on Physical characteristics during transformation from paddy to flaked rice.

3.2 True density, bulk density and porosity

Bulk density of Chhattisgarh Zinc Rice paddy variety ranged from 431.20 to 440.40 kg/m^3 for thick sized flaked rice and 220.60 to 232.80 kg/m^3 for thin sized flaked rice. Whereas, the true density of Chhattisgarh Zinc Rice paddy variety ranged from 1250.06 to 1282.05 kg/m^3 for thick flaked rice and 1000.00 to 1115.78 kg/m^3 for thin flaked rice. The decrease in density (both bulk and true) of thin flaked rice is significant with respect to intact grains. Flaking process decreases the voids existing within the sample particles resulting in an ordered arrangement of particles and consequently lowering down the density, Mohapatra and Bal (2012). Porosity of Chhattisgarh Zinc Rice paddy variety ranged from 64.36 to 67.52 % for thick sized flaked rice 76.71 to 80.06 % for thin sized flaked rice (see Table 2).

3.3 Angle of repose and static coefficient of friction

Angle of repose is an effective physical property in food processing sector for the design of hopper for milling and packaging equipment ranged from 35.75 to 37.80 degree for thick and 42.61 to 43.85 for thin flaked rice of Chhattisgarh Zinc Rice paddy variety. Coefficient of static friction for thick flaked rice at different surfaces materials was found to range from 0.50 to 0.54 on glass, 0.40 to 0.46 on plywood and 0.44 to 0.50 for GI sheet respectively. Similarly, Coefficient of static friction for thin flaked rice at different surfaces materials was found to range from 0.46 to 0.52 on glass, 0.40 to 0.48 on plywood and 0.44 to 0.48 for GI sheet respectively. Coefficient of static friction was highest on glass for thick flaked rice and lowest on plywood surface. The reason may be the irregular surface of flaked rice that creates friction between surface and materials. Similar results were also reported by Ghasemi *et al*. (2008) (see Table 2).

Table 3:

Parameter	Chhattisgarh Zinc Rice paddy variety		
	Paddy	Thick flaked rice	Thin flaked rice
Bulk density (kg/m^3)	578.99 ± 17.09	435.80 ± 5.74	226.70 ± 0.84
True density (kg/m^3)	1114.55 ± 41.46	1266.05 ± 52.96	1057.89 ± 85.34
Porosity (%)	47.89 ± 1.25	65.94 ± 1.49	78.38 ± 1.46
Angle of repose (°)	34.80 ± 0.73	36.77 ± 0.77	43.23 ± 0.63
Coefficient of friction (glass)	0.45 ± 0.04	0.52 ± 0.02	0.49 ± 0.03
Coefficient of friction (plywood)	0.46 ± 0.03	0.43 ± 0.03	0.44 ± 0.04
Coefficient of friction (GI sheet)	0.48 ± 0.04	0.47 ± 0.03	0.46 ± 0.02

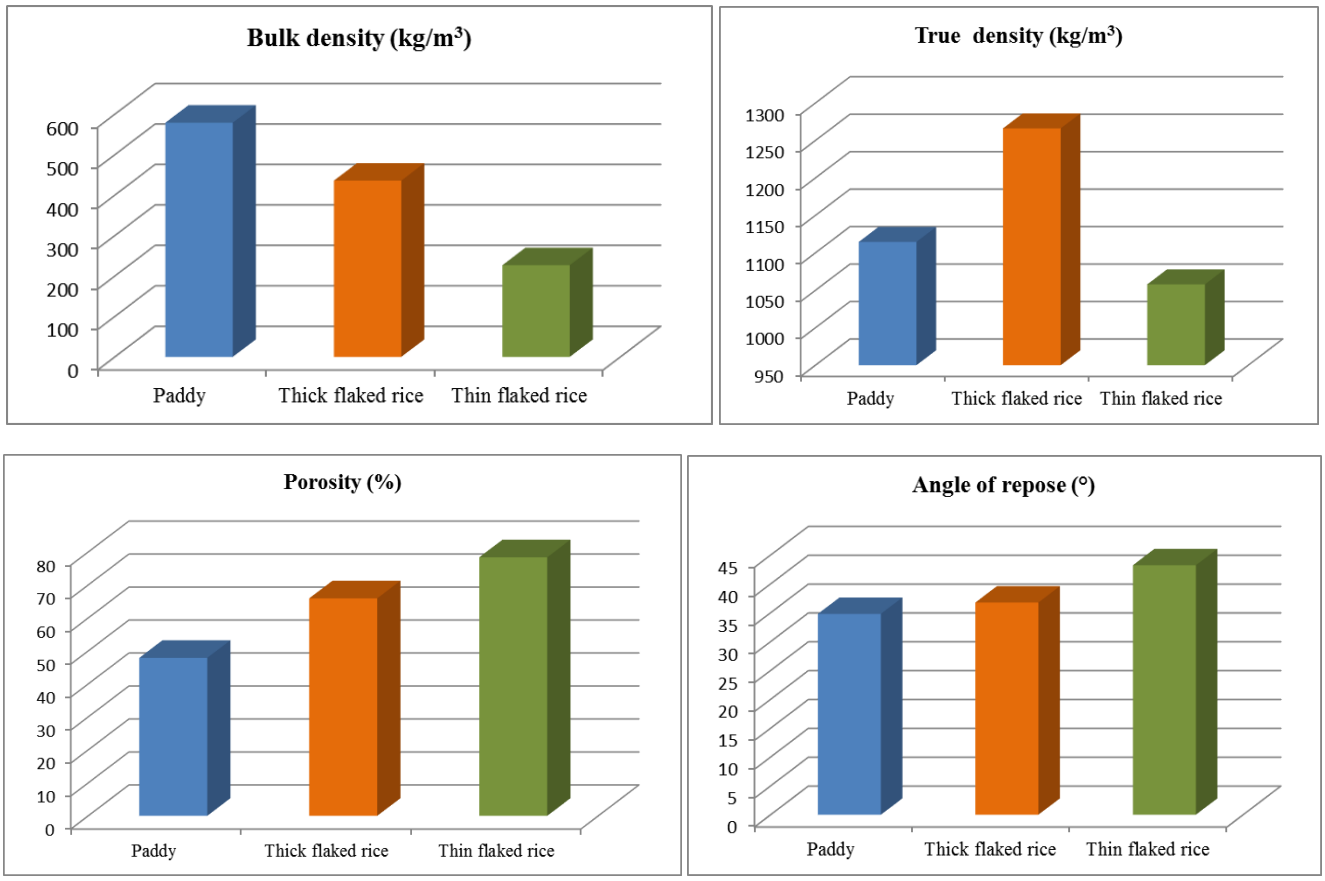
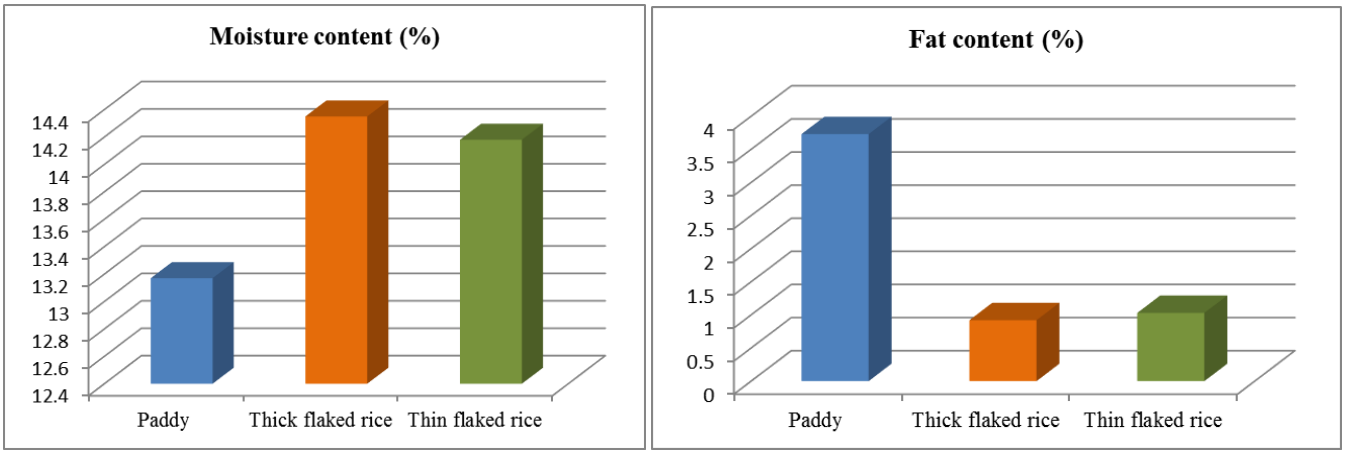


Fig 3: Effect on gravimetric and frictional properties during transformation from paddy to flaked rice

The results of chemical and functional properties of brown rice, thick and thin flaked rice are shown in Table 3. Moisture content was higher in thick and thin flaked rice as compared to brown rice, Due to soaking process the paddy kernel absorbs water resulting in its increased moisture content. Fiber content, protein content, and total ash content of brown rice, thick and thin flaked rice were almost similar (Table 3). Whereas the fat content of brown rice increased significantly than thick and thin flaked rice ($p > 0.05$) due to present of bran in brawn rice. Amylose content in brown rice was significantly higher than thick flaked rice. Processing of paddy into flaked rice at high temperature results in starch gelatinization with a portion of amylose getting converted into resistant starch yielding flaked rice with higher resistant starch content in the process of rice parboiling (Chitra *et al.*, 2010: Mahanta and Bhattacharya, 2010: Ibukun, 2008) [3, 10, 8] (see Table 4).

Table 4: Chhattisgarh zinc rice paddy

Parameter	Chhattisgarh Zinc Rice paddy variety		
	Brown rice	**Thick flaked rice**	**Thin flaked rice**
Moisture content (%)	13.17 ± 0.38	14.35 ± 0.17	14.18 ± 0.15
Fat content (%)	3.58 ± 0.17	0.92 ± 0.08	1.03 ± 0.06
Fiber content (%)	3.73 ± 0.49	2.47 ± 1.53	2.00 ± 1.00
Protein content (%)	5.55 ± 0.52	5.12 ± 0.38	4.97 ± 0.46
Ash content (%)	1.05 ± 0.10	1.49 ± 0.35	1.24 ± 0.05



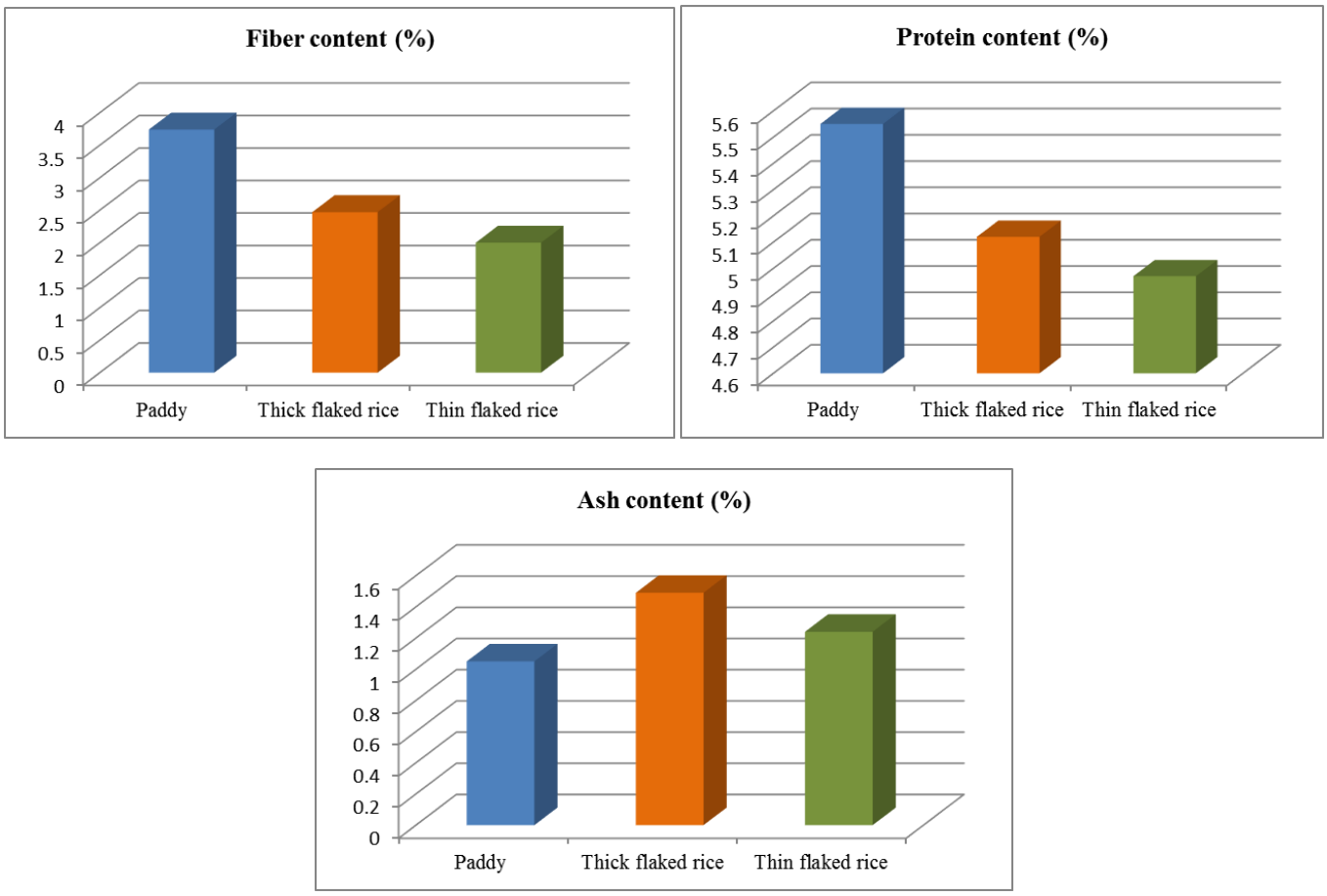


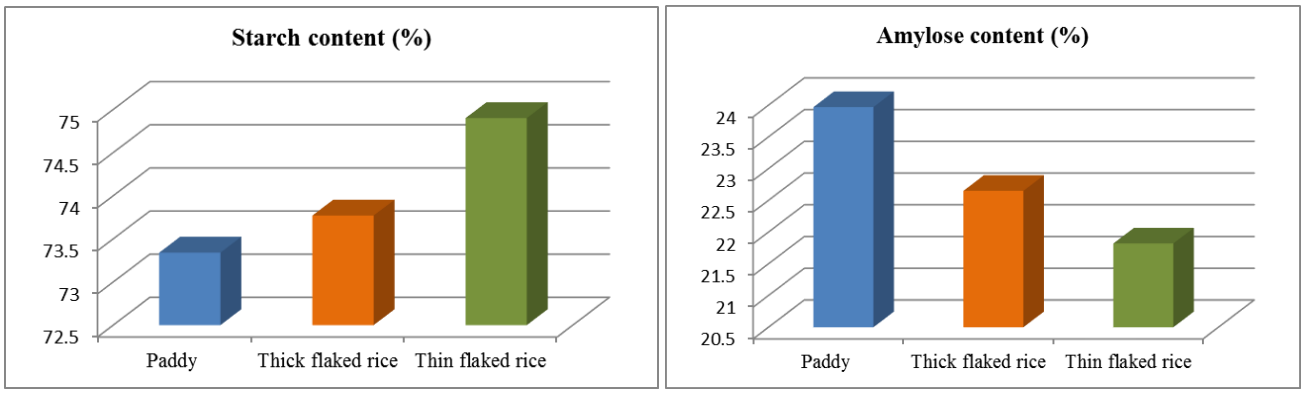
Fig 4: Effect on Proximate analysis during transformation from paddy to flaked rice.

3.4 Water absorbing index (WAI) and water solubility index (WSI)

The WAI and WSI of brown, thick and thin flaked rice are shown in Table 4. The WAI and WSI of flaked rice increased significantly ($p > 0.05$) during the processing of paddy. WAI of thick and thin flaked rice was found to be greater than the brown rice. Processing of paddy to flaked rice resulted in physicochemical changes of grains. Roasting at high temperature resulted in decreasing moisture content of grains that led to the dry heat gelatinization. Both roasting and flaking resulted in the damage of some starch granules leading to their enhanced water absorption capacity. (Kumar *et. al*. 2016) [9].

Table 5: Rice paddy

Parameter	Chhattisgarh Zinc Rice paddy variety		
	Brown rice	Thick flaked rice	Thin flaked rice
Starch content (%)	73.34 ± 3.20	73.77 ± 0.96	74.90 ± 1.37
Amylose content (%)	23.97 ± 0.82	22.65 ± 0.16	21.82 ± 0.25
Amylopectin (%)	76.03 ± 0.82	77.26 ± 0.16	78.03 ± 0.25
Water absorbing index (g/g)	2.49 ± 0.24	5.62 ± 0.29	5.10 ± 0.05
Water solubility index (%)	4.02 ± 1.03	6.29 ± 1.11	6.66 ± 0.75
Swelling power (%)	6.20 ± 0.04	6.08 ± 0.36	5.60 ± 0.21



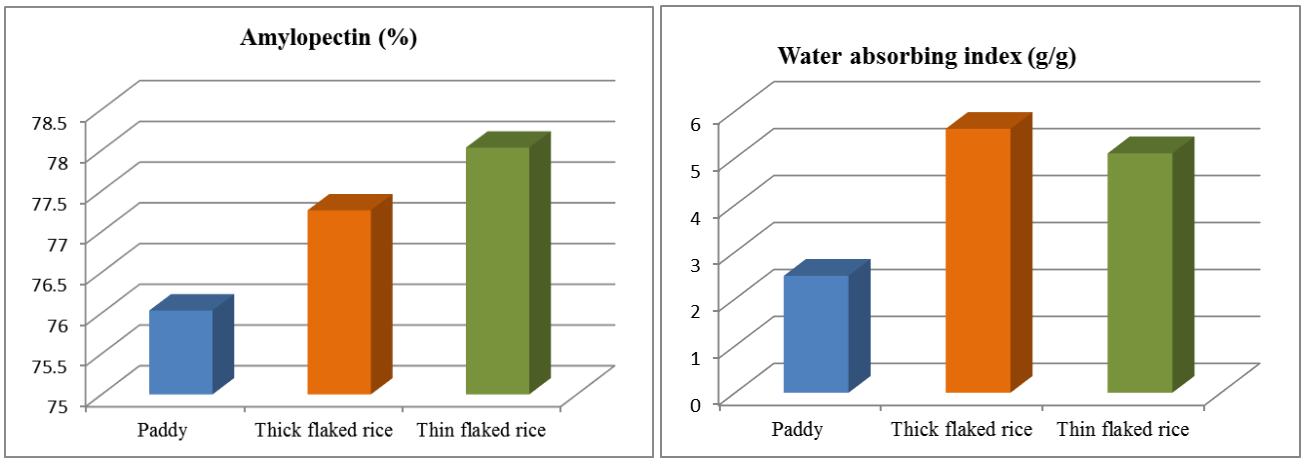


Fig 5: Effect on Chemical and functional properties during transformation from paddy to flaked rice

4. Conclusion

It has been observed that all the physical, gravimetric properties of flaked rice were significantly ($p>0.05$) difference in values after flaking process of paddy. Bulk density (BD), and true density (TD) of flaked rice were lowest as compared to other products. Frictional properties did not show any significant difference ($p<0.05$) except for angle of repose. Significant difference was observed in functional properties of flaked rice with increase in water absorption index (WAI) and water solubility index (WSI). It has been also observed that all the proximate analysis (fat content, fiber content, and protein content) of flaked rice for thick and thin size among all varieties were not significant difference but for ash and moisture content, significantly ($p<0.05\%$) difference was observed. In case of chemical analysis of flaked rice amylose and Amylopectin of thick and thin size among all varieties were significantly ($p>0.05\%$) difference except to starch content.

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