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Comparative study of different properties of conditioned rice before and after puffing

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ABSTRACT

Puffed rice has got a highest demand both in national and international market. Quality factors such as uniform puffing, contamination free, good color, crispiness etc are the major concern for export of puffed rice. However, the production of puffed rice in India is only limited to village levels. The pre-puffing conditioning (preconditioning) of rice is the most critical factor for achieving the good quality expanded product. It is basically uniform and slow heating of high moisture (water soaked) parboiled grains coupled with turning or agitation. This facilitates proper structural changes of grains like, surface modifications and hardness, removal of moisture and thus produces highly expanded and smooth surfaced puffed rice. This study gives the comparison study of different characteristics of conditioned rice before puffing and after puffing showing the different changes which occurs physically and structurally.

Key words: *Conditioned rice, puffed rice, SEM, hardness, crispiness*

INTRODUCTION

Breakfast has long been known to be the most important meal of the day because it provides the energy and nutrients needed to "break the fast" and to get energy for body and brain after a long night's sleep. The consumption of cereals in the morning is associated with eating of more carbohydrates and fibers and consuming less fats. Rice is used as an important staple food by the people in many parts of the world after wheat (Ghadge and Prasad, 2012). Many breakfast cereals are made from whole grains and provide fibre. India produces annually 89 million tonnes of rice (second largest producer of rice in the world), but, only 10 percent of it is converted to different value added products such as puffed rice, popped rice or flaked rice. The milled grains are treated with salt water to an optimum moisture content, which is then subjected to puffing by sand roasting method. Consumption of these may thus be been linked to reduce the prevalence of disease risk (FDA, 2006). Ready-to-eat cereals are processed grain formulations suitable for human consumption without requiring further cooking. Puffed cereals are commonly used as ready-to eat breakfast foods or as ingredients in snack formulations. They are appreciated mainly for their lightness and crispiness, qualities related to their cellular structure (Peleg, 1997) and degree of expansion (Owusu-Ansah et al.,1984). Cereals may be puffed in several ways, but oven and gun puffing are the two technological processes generally used.

Expansion of the water vapour occurs when the pressure is suddenly released, blowing up the grains or cereal pellets to several times their original size (8-fold to 16-fold for wheat, 6-fold to 8-fold for rice). The final product is toasted to a moisture content of about 3 percent to achieve desired crispiness. In processing wheat, a preliminary step may be applied to free the grain from much of its bran coatings. Puffed rice have a very porous matrix, made up of numerous cavities of different sizes separated by a very thin 'wall'. Moreover, puffing induces significant changes in the structure and physical properties of the starch and an increased water holding capacity of grains(Mariotti et al., 2006)).

Non-uniform heating of grains severely impairs the puffing quality and rough and blistered puffed rice. This laborious and tedious process of conditioning necessitates replacement with a developed mechanical system to produce uniformly conditioned rice for improving puffing quality. It is proposed that the results of puffing are caused by the vaporization of superheated water. The simultaneous flash-off of vapor expands the grains, resulting in a porous, sponge-like structure within the product. Therefore, moisture content plays an important role in the texture of puffed rice (Moraru et al., 2003).This is the study of characteristic difference between rice and puffed rice.

MATERIALS AND METHODS

Properties of Rice & Puffed Rice

Conditioning of rice

The clean milled rice was pre-treated before puffing by using one of two methods. In the first method, the clean rice was tempered to 18% moisture content at 4°C for 16 h. In the second method, the clean rice was soaked at 25°C for 1h and then steamed at 95°C for 1h, and finally dried at 70% RH and 45°C for 14 -16 h in a drying chamber until the moisture content of the treated rice reached 13 ± 1%. (Chandrasekhar and Chattopadhyay, 1990; Owusu-Ansah et al., 1984, Dash and Mohapatra, 2011).

The parboiled rice was bought from khurda rice mill. Then salting was done by mixing 2kg of salt for 150kg of rice with about 20 l of water. A 6% milling (minimum) and a 2% salt ($NaCl/CaCl_2$) addition during preconditioning of rice resulted in maximum expansion ratio (Chandrasekhar and Chattopadhyay, 1991; Maisont S and Narkrugsa W, 2010). It was left for sun drying for about 5h. Then the rice clods are separated by mixing with hands and stirred simultaneously. For heating purpose, gas cylinders were used. The conditioned rice was exposed to heat in a kadhhai and stirred simultaneously. The rice was conveyed to the drum with preheated sand. The sand was heated using dry leaves, woods, etc. When fumes come out of the sand, it is now fully heated to a temperature of 250°C , it takes about 20-25 s. Optimum puffing was obtained by heating milled parboiled rice at a moisture content of 10.5-11% with 15 times its weight of fme sand at 250°C for 10-11 sec(Chandrasekhar and Chattopadhyay, 1983a,b). Rice was puffed in the drum. Puffed rice along with broken, unpuffed rice and sand particles was passed to a rotating sieve for separation. The puffed rice was packed.

Moisture content

The initial moisture content determined and expressed on dry basis (AOAC, 2000). A temperature controlled oven was used. The temperature was kept not higher than specified because otherwise chemical changes occur within the grain which can cause additional weight loss. The oven was set at 100ºC. Three rice samples of 25g weight each and along with that 5g of puffed rice each was taken and placed inside the oven. The final weight of the samples was taken after 36 hours. Moisture content (MC_{db}) was calculated in dry basis by weight of moisture (W_i-W_f) where, w_i is the intial weight and w_f is the final weight divided by final weight (w_f) of material.

$$MC_{db} = \frac{W_i - W_f}{W_f} \times 100$$

Bulk density

The bulk density is the mass of a group of individual particles divided by the total volume, including the air space. It was determined using the relationship by filling an empty plastic container or predetermined volume (1l) and tare weighed with the puffed rice by pouring from a constant height, striking off the top level and weighing. Then the weight of the sample was divided by volume and is expressed in g/cm^3. The same process was followed for the determination of bulk density of the rice.

$$\text{Bulk Density} = \frac{(\text{Weight of Sample})}{(\text{Volume of Sample})}$$

True density

It is the ratio of the mass of a grain sample to the solid volume occupied by the sample.

True Density of rice

It was calculated for the rice using pycnometer and toluene displacement method. Pycnometer with stop cock was weighed in a balance (say W_1). Then it was filled with toluene and weighed (say W_2). The pycnometer with rice was weighed (say W_3). Lastly pycnometer with rice and filled with toluene was weighed (say W_4). Specific gravity of toluene was multiplied.

Sp. Gravity of liquid toluene= 0.865

$$\text{True density} = \frac{(W_3 - W_1)}{(W_2 - W_1) - (W_4 - W_3)} \text{ x sp. gravity}$$

True Density of puffed rice

For the true density of the puffed rice sand, displacement method was used. Puffed rice was filled in a 1ltr beaker and weighed. Then the void space was filled with fine sand, sieved in a sieve of aperture size of 0.250 mm gauge. The sand was separated from the puffed rice and weighed. True volume of puffed rice was obtained by measuring the volume of puffed rice with void space filled with fine sand and subtracting the volume of the separated sand. Then the weight taken was divided by the volume of the container to obtain the true density.

$$\text{True density} = \frac{\text{(weight of sample)}}{(v_1 - v_2)}$$

Volume of puffed rice (v_1)
Volume of fine sand (v_2)

Porosity

It is a property of grain that depends on its bulk and kernel densities. ε is the percentage of air between the particles compared to a unit volume of grains and it was computed as:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \text{ x } 100$$

Where ,
ρ_t = true density
ρ_b = bulk density

Expansion ratio (er)

The expansion ratio was determined by taking the ratio of the bulk density of rice to that of the expanded product (Lai and Cheng, 2004)

Textural analysis

Samples of puffed rice were taken and tested for determining the crispiness of puffed rice by bulk compression.

Sample Preparation

Samples of puffed rice are removed from place of storage just prior to testing and weighed into equal portions. It is important that this weighed amount is enough to approximately fill the Ottawa cell. 35mm Cylinder Probe (P/35) using 50kg load cell was used. Two pellets were positioned, centrally under the probe. The compression test was commenced for ten samples of rice and puffed rice sample. Samples were removed from storage just prior to testing to avoid moisture uptake from the atmosphere.

Structure of rice and puffed rice

Raw grains and puffed grains were observed. Samples were mounted on aluminium stubs. Their ultrastructure was imaged in the scanning electron microscope (SEM) under high vacuum conditions (10KPa) at an accelerating voltage of 20 kV. The highly magnified images were captured .

RESULTS AND DISCUSSION

Moisture content

The average moisture content for conditioned rice and puffed rice was found out to be 8.84% and 6.75% respectively (Table 1). It was observed that due to exposure to heat during puffing process moisture was lost from the conditioned rice, which enhances the crispiness of puffed rice.

Bulk density

Bulk density of rice and puffed rice are 0.829g/cm^3 and 0.0975g/cm^3 respectively. The high value for bulk density of rice might be attributable to the greater compactness of the starchy endosperm of rice which

Table 1. Comparison of properties of conditioned rice and puffed rice.

Parameter	Conditioned rice	Puffed rice
Moisture content (%)	8.84	6.75
Bulk Density(g/cm^3)	0.829	0.0975
True Density(g/cm^3)	1.476	0.390
Porosity (%)	43.83	75
Toughness (gs)	-	114240.057
Fracturability (gs)	-	121268.189
Crispiness (%)	-	40

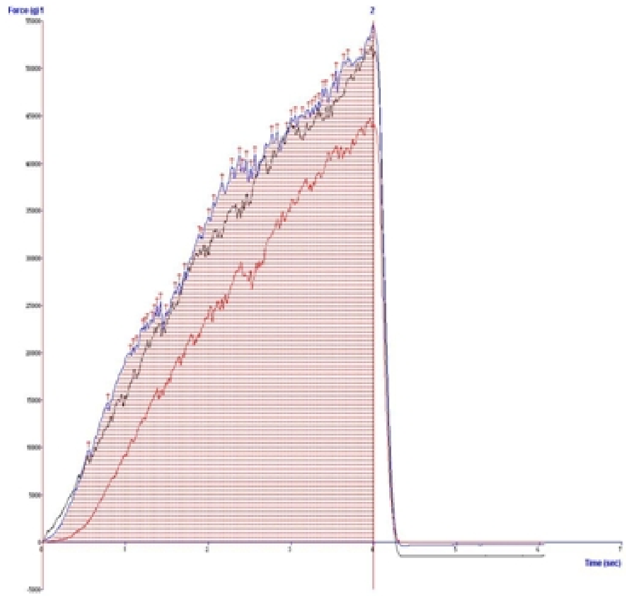

Fig. 1. Texture profile of puffed rice.

is indeed characterized by a higher apparent density. But the puffing process caused a drastic decrease in the bulk density due to high degree of expansion.

True density

The value of true density was determined to be 1.476 g/cm^3 for rice and 0.390 g/cm^3 for puffed rice. True density is more for rice than puffed rice due to expansion in case of puffed rice.

Porosity

Porosity of rice was found out to be 43.83% while porosity of puffed rice was 75%. This increased value is due to the increase in pore space due to puffing.

Expansion ratio

The expansion ratio after puffing was found to be 8.50.

Crispiness, fracturability and toughness of puffed rice

Once the plunger has reached the sample (from a starting position of 60mm from the base), force is seen to increase at a steady rate. As the plunger moves down further onto the sample the force begins to increase rapidly as the sample begins to fracture.All data are mentioned in Table 1 for conditioned rice and puffed rice.

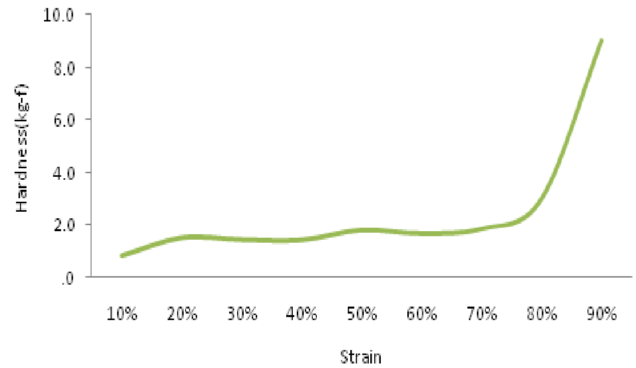

Fig. 2. Strain vs hardness (Puffed rice).

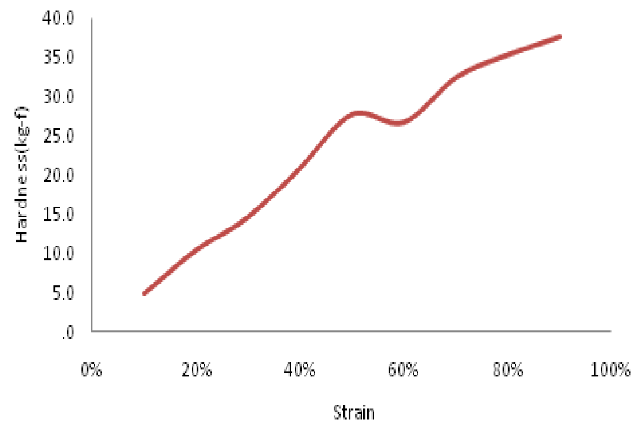

Fig. 3. Strain vs hardeness (Conditioned rice).

As compression proceeds, fracturing can be observed as a series of force peaks. The number of picks was obsfierved to be crispiness, the linear distance as fracturability and the area under the curve as toughness. A typical texture analysis figure is shown as in Fig. 1.

The fracturability of puffed rice was observed to be between 104405.949 gs and 134384.929 gs with average value of 121268.189 gs. The crispiness was observed to be between 35 and 45 with average value of 40. The toughness was found to be 87335.010 gs to 121828.559 gs with average value of 114240.057 gs.

Hardness

Rice and puffed rice were subjected to 10% to 90% compression and the hardness was determined. This hardness analysis by with respect to strain can be seen in Fig. 2 and Fig. 3 for puffed rice and conditioned rice before puffing.It was observed for puffed rice that the hardness increased upto 14.74 N in case of 10% and 20% strain indicating all the force was absorbed by the

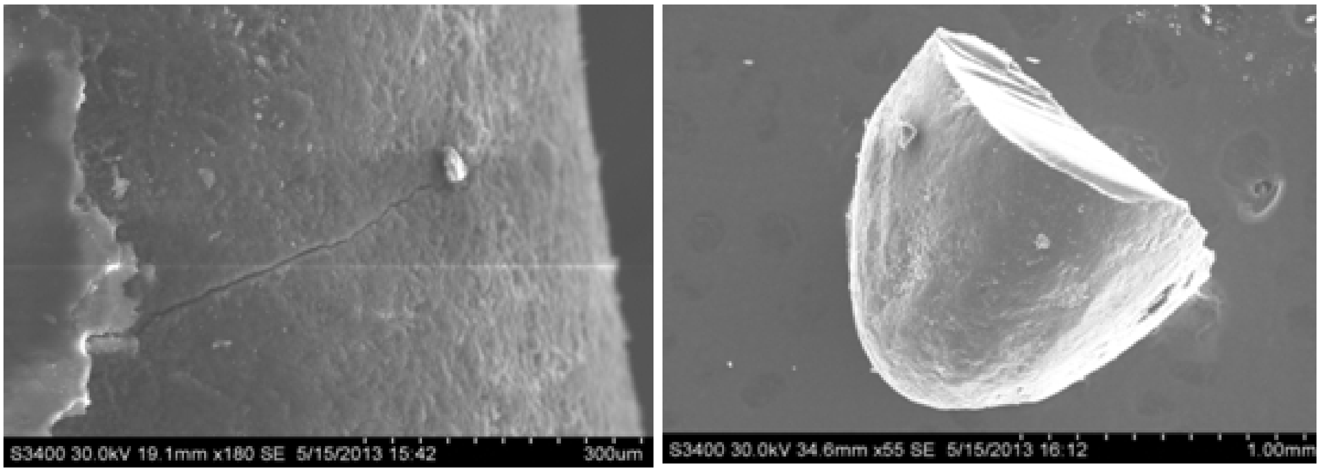

Fig. 4. SEM image at 20% and 90% strain for conditioned rice.

puffed rice. When the puffed rice was subjected beyond 20% strain, it was observed that the hardness increased upto 88.58 N when compressed upto 90% strain and there was no increase of hardness even though the strain was increased from 20% to 80% indicating the bio-yield. This phenomenon of change in hardness in texture (glass transition) is common in foods due to change in moisture content with time.(Roos and Karel, 1991).

Test results obtained from 9 samples (conditioned rice and puffed rice) gives the following typical mean maximum force values.

Hardness of puffed rice Strain at 20% to 80% shows there was an equal amount of strain absorbed and at 90% it breaks completely so the hardness rapidly increases.

Hardness of rice When the force given to the rice is increased, it was absorbing the strain upto 40%. But beyond that at 50% strain it breaks and further it was observed that as the force increases time also increases with it.

There was a gradual increase in hardness but when the rice breaks at 50% strain there was a sudden change showing the deformation in rice .

Grain characteristics The SEM images of transverse section of the grains before and after puffing showed considerable structural differences between the rice and puffed rice. Before puffing, all grains had an internal structure that was compact and relatively homogeneous. The whole rice grain shows no rupture on the surface and then at increased strain it shows cracks on the surface where there is no gelatinization and further the cracks also increased. These are the

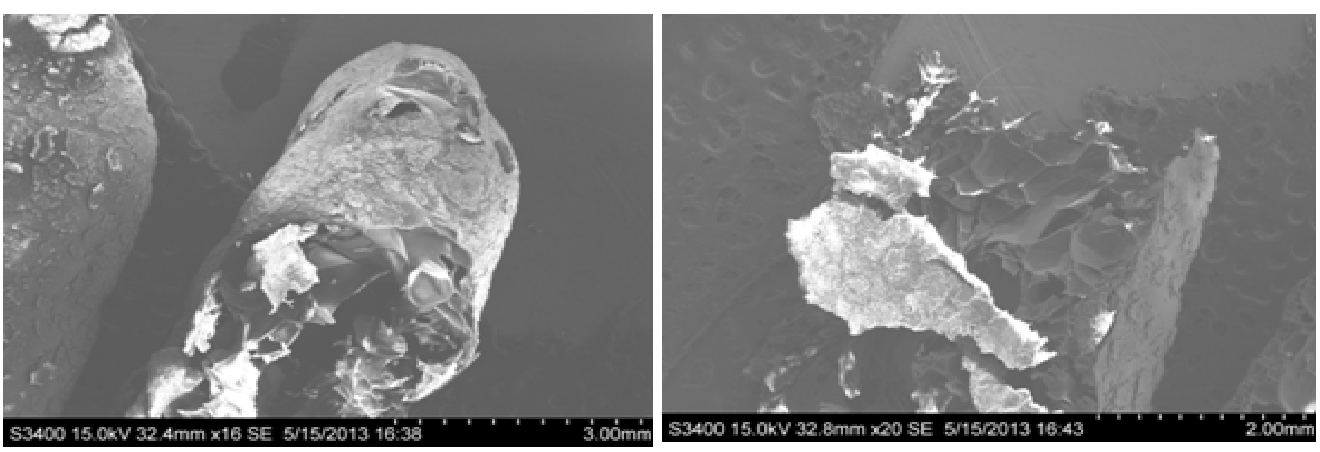

Fig. 5. SEM image at 20% and 90% strain for puffed rice.

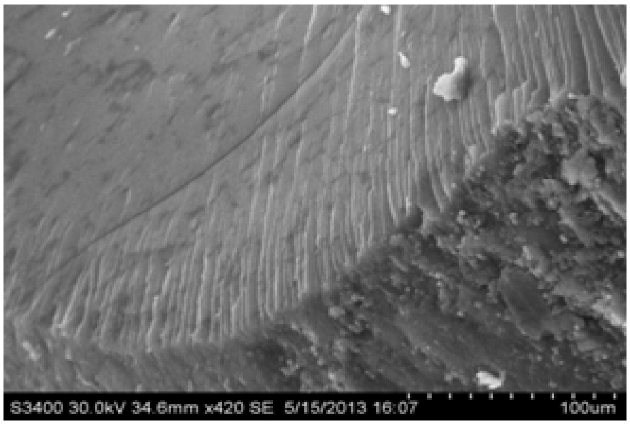

Fig. 6. Salt granules in rice.

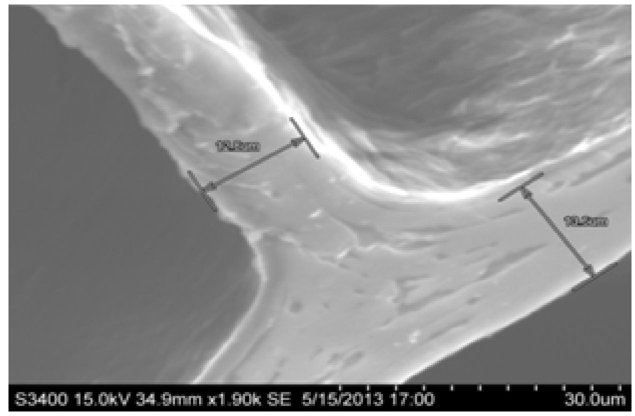

Fig. 8. Showing puff wall thickness.

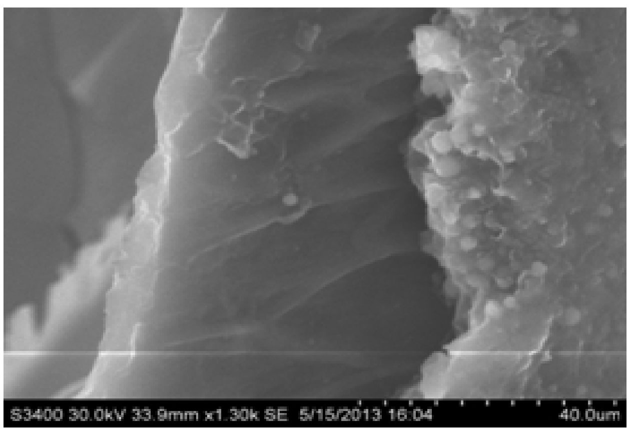

Fig. 7. Gelatinised starch of parboiled rice.

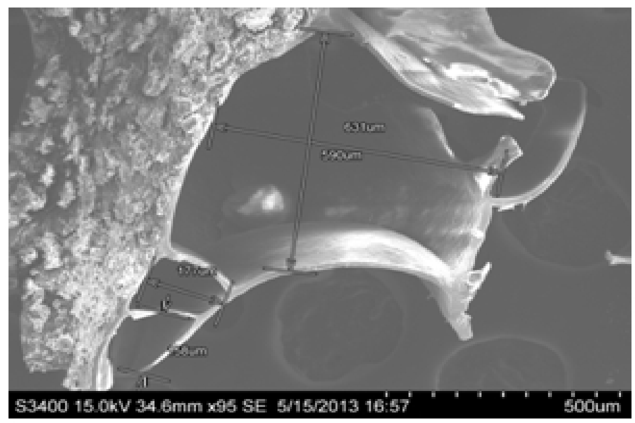

Fig. 9. Void space of a puffed grain.

primary cracks at a less strain but at increased stress the rice begins to break at strain of 70% and 80% as shown SEM image in Fig. 4. At minimum strain of 10% the puffed rice starts cracking. As the strain increased it was found that the puffed rice completely breaks as shown in SEM image in Fig. 5. The white granules are the salt added to the rice during the conditioning processes shown in Fig. 6. Generally salt particles remain at the surface of the rice particles. Fig. 7 shows the fused & gelatinized starch surface of the rice due to parboiling.

From Fig. 8 it was observed that the wall thickness surrounding the pore spaces varies from 12.8 micron to 13.6 micron. Average dimension of sample puffed rice was observed to be 1.10 mm length and 463 μm thickness. The pore spaces are observed which are of different sizes ranging from 158- 631 μm. This can be observed from the Fig. 9.

CONCLUSION

From the above study the following conclusions were drawn. The average moisture content for conditioned rice and puffed rice was found out to be 8.84% and 6.75% respectively. Bulk density of rice and puffed rice are 0.829 g/cm^3 & 0.0975 g/cm^3 respectively. The value of true density was determined to be 1.476 g/cm^3 for rice & 0.390 g/cm3 for puffed rice. Porosity of rice was found out to be 43.83% while porosity of puffed rice was 84.24%.The crispiness of puffed rice was observed to be 40%. The expansion ratio was determined to be 8.50.The fracturability was observed to be an average value of 121268.189gs. The toughness was found to be an average value of 114240.057gs. The hardness was found to be an average value of 24.54 N and 228.72 N respectively for puffed rice and rice. It was found that there was permanent deformation at 50% & 80% strain for rice and puffed rice respectively. It was observed in SEM that cracks generally develops at no or less gelatinized surface at lower strain cracks develop horizontally and at higher stain it is longitudinal. Also observed that the salt always remains on the surface and don't penetrate inside.

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