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Accelerated ageing of paddy and its effect on paddy milling characteristics and physico-chemical and textural properties of milled rice

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Abstract
In Indian subcontinent as well as in some Asian countries, naturally aged rice is generally preferred. Natural ageing is done by storing harvested paddy for at least 4-6 months to 2 years. Accelerated ageing is an artificial technique that induces ageing effect in the rice within a short period of time. In this study one of the many such techniques was employed for accelerated ageing of paddy. Hydrothermal treatments were imposed on paddy i.e., soaked in water @ room temperature of 28 °C for 2 min, steamed at three pressures (0.0, 0.5 and 1.0 kg/cm^2 gauge) for 5 - 15 min, dried to 14% moisture in shade and then milled in order to study milling, physico-chemical and textural characteristics of rice. Among all the treatments studied, paddy @18% initial moisture, exposed to wet steaming of 0.5 kg/cm^2 for 10 min was found to be best for accelerated ageing of paddy.

Keywords: Accelerated ageing, hydrothermal treatment, Physico-chemical, textural characteristics

Introduction

Rice (*Oryza sativa* L.) is one of the leading food crops of the world and is a staple food of over one-half of the world population. Rice provides more calories per hectare than any other cereal crop. Its nutritional level is high among cereals and other grains. Among cereals, it contains comparatively higher amounts of essential amino-acids. Though the protein content of rice is less than that of wheat, the true protein digestibility and the biological value of rice protein are the highest among cereals including wheat. Rice provides 20% of the world’s dietary energy supply, while wheat supplies 19% and maize (corn) provides 5%. The proximate composition of brown rice (per 100 g) is - protein 7.3 g, crude fat 2.2 g, fibre content of 6.8 g, available carbohydrates 71.1 g and 384 kcal of energy [1].

Freshly harvested rice, when cooked, usually becomes a sticky or pasty mass, swells only slightly and losses a fair amount of solids (starch) into the cooking water yielding a thick gruel. It also splits more on sides during cooking. However, upon storage for a minimum period of 4 to 6 months, the rice swells more with less stickiness; the gruel becomes thin; its linear elongation upon cooking is more than in fresh rice. In addition, the aged rice has higher volume expansion ratio and water absorption and results in less dissolved solids on cooking. Preferences for new or old rice differ among different populations. In India the preference is strong for the stored rice and ageing of rice is a desirable attribute.

During ageing of rice, a number of physiochemical properties of the rice change [2]. The cooking and eating properties of rice change dramatically with its storage after harvest and this phenomenon is called ‘ageing of rice’. It is a physico-chemical process during which its properties like hydration, swelling, solubility, viscosity and pastiness change. Rice from freshly harvested paddy cooks into a pasty consistency. It is mainly due to disintegration of fresh rice, leading to dispersion of starch granules in the cooking water. Pastiness can be eliminated if the grain can be hardened so as to minimise the loss of solids in the gruel. The process of inducing the changes in rice in a short time to obtain cooking properties, which resemble to that of naturally aged rice, is referred to as *accelerated ageing of rice*.

Some rice varieties require quality enhancement particularly with respect to cooking and eating quality through the ageing process. Under the normal situations, these varieties require at least 4 months of ageing period. As this process involves holding cost, it is therefore necessary to accelerate ageing not only to minimise processing cost but also storage losses.

The accelerated ageing treatment brings about only a partial gelatinization of the starch and the process is more economical than the traditional process to obtain aged rice.
Many techniques were tried both on paddy and milled rice for accelerated ageing to obtain ‘aged rice’. Some of the works are discussed below:

Method #1: A method for the accelerated aging of rice, comprising the following steps: i) Selecting and dividing paddy into uniform batches depending on moisture, processing yield, amylose content and gelatinization temperature; ii) Humidifying a paddy batch so that the grain reaches a moisture content of 15-25%, preferably 18-20%; iii) Applying heat treatment using microwaves so that the grain reaches a temperature of 50-70°C, preferably of 55-63°C, without significant moisture loss; iv) Gelatinizing-pre-drying in closed environment and at a temperature of approximately 2-4°C higher than the gelatinization temperature of the variety processed, while keeping the temperature, moisture and ventilation controlled so as to cause a controlled and partial gelatinization of the grain, limited only to the outer layer; v) Drying with ventilation and with air temperature of the air of 30-35°; vi) Resting or tempering without ventilation with temperature of the air of 30- 35°C; vii) Rapid cooling with air in forced closed circuit

Method #2: Microwave heating treatment (MWH) was tried for accelerated rice ageing. Freshly harvested *indica* cultivar paddy was sun dried to < 14% dry basis and then microwave heat treated at two power levels (1,000 and 2,000 W) and six exposure times (23, 26, 31, 41, 66, and 159 seconds). The head rice yield, colour and gel consistency were determined for microwave-treated and untreated sample (control). Texture of cooked rice grains, pasting properties and gel texture of rice were optimum for 41 seconds treatment [3].

Method #3: High-temperature fluidized-bed drying technique in combination with tempering step was used for accelerated ageing of rice [4]. The quality of rice dried at temperatures of 130 and 150°C and tempered for 30 to 120 min was compared to that of brown rice stored at ambient temperature (≈ 30°C) for 7 months. The results showed that the cooking and eating properties of the fluidized bed dried rice i.e., hardness, solid loss, volume expansion and elongation ratio changed in a similar fashion as that of the conventionally aged rice.

Method #4: Three different rice cultivars varying in length breadth ratio to study accelerated aging. Paddy was conditioned to 14, 18 and 22% moisture content (wet basis) and then steamed for 30 min at atmospheric pressure. After drying, the paddy was dehusked to obtain brown rice and then polished to white rice. The physicochemical and textural properties of brown and milled rice were determined using an Instron Universal Testing Machine. Steaming at higher levels of moisture content increased elongation, width expansion, water uptake, cooking time and decreased solids loss. The hardness, cohesiveness and springiness of cooked rice increased where as its adhesiveness decreased. The extents to which these changes occur seem to depend upon the moisture content of the paddy before steaming and duration. At higher moisture levels, the severity of the treatment increased due to increased starch gelatinization. Accelerated aged rice can be prepared by this short-time process to yield rice that has better and more desirable cooking properties [5].

Method #5: The paddy of higher initial moisture and dried at high drying temperature with longer tempering time significantly affected the aged rice properties. The drying temperature of 150°C, initial moisture content of 33% (d.b.) and tempering time of at least 90 min were recommended as the most suitable conditions for accelerating the rice aging process. However, the head rice yield of paddy that underwent thermal treatment was significantly lower than that of the naturally aged paddy [6].

Method #6: Using an incubator, rice grain samples (var. BPT 5204 and BPT 2270) were incubated at 90, 100, 110 and 120ºC for 1, 3, 5, 7 and 9 h and then the samples were cooled at room temperature for 1 h. The samples were drawn at an interval of 30 days for analysis of quality parameters like elongation, elongation ratio, swelling index, hardness, carbohydrates, protein content and amylose content, for both artificial and natural ageing. It was observed that in BPT 5204, the highest elongation and elongation ratio were respectively 2.111 mm, & 1.450 for natural ageing; and 4.732 mm & 1.976 for artificial ageing. In BPT 2270, the highest elongation and elongation ratio were respectively 2.471 mm & 1.472 for natural ageing; and 5.460 mm & 2.049 for artificial ageing. Swelling index, Hardness and Amylose content had slightly increased with the ageing where as protein content, carbohydrates and colour decreased with the ageing. By analyzing the obtained results, it could be concluded that to get a good elongation ratio for BPT 5204, BPT 2270 ageing at 110°C – 3h in fifth month and 100°C – 3h for sixth month is best and convenient [7].

Method #7: For accelerated ageing, paddy was heated at 60, 70, and 80ºC for 6, 10, and 24 h. Then the samples were evaluated and compared to non-ageing rough rice in terms of paddy hardness, milled rice hardness, cooked rice hardness, gel consistency, volume expansion of rice kernel and milling quality. It was found that temperature affected the properties whereas time has no effect and 70ºC was the best condition in this experiment [8].

Material and Methods
The present research work was undertaken to study the effect of some hydrothermal treatments on paddy on ageing of rice.

Procurement of Paddy
Paddy variety used in the present study was *Gangavati sona*, a popular fine grain paddy, in Karnataka. Freshly harvested paddy was procured from a farm in Gangavati, Karnataka and was shade dried to 14% (wb) moisture content. A control sample was packed and stored at ambient temperature (≈28±2°C) of Bangalore conditions for about 6 months for natural ageing.

Hydrothermal treatments for accelerated ageing
Paddy (@14% moisture) was soaked in room temperature water (≈28°C) for just 2 minutes (grain to water ratio 1:2). After soaking, the water was drained out using a strainer and the moisture content of paddy after 2 min soaking was observed to be about 27%. The soaked grain was steamed in the autoclave at 3 different steam pressures of 0, 0.5 and 1.0 kg/cm^2 for the durations of 5, 10 and 15 minutes. After steaming, the accumulated moisture in the paddy was removed by sun drying to obtain a final moisture content of about 14% (wb). About 500 g of paddy was used in each trial and each treatment was replicated twice.

Milling of Treated Paddy Samples

The treated paddy samples of various accelerated ageing treatments were de-husked using a laboratory rubber roll paddy sheller, polished using an abrasive grain polisher and aspirated to remove bran using an aspirator. Then the rice brokens were separated using rice broken separator. The following equations were used for calculating various milling characteristics of treated paddy:

$$\text{Milling yield (\%)} = \left(\frac{\text{Weight of brown rice (kg)} \times \text{Weight of milled rice(kg)}}{\text{Weight of paddy (kg)} \times \text{Weight brown rice polished(kg)}}\right) \times 100$$

$$\text{Head rice yield (\%)} = \frac{\text{Weight of head rice (kg)}}{\text{Weight of milled rice (kg)}} \times 100$$

$$\text{Brokens (\%)} = \frac{\text{Weight of brokens (kg)}}{\text{Weight of milled rice (kg)}} \times 100$$

Determination of Physico-Chemical and Cooking Properties of Milled Rice

Cooking characteristics of polished rice samples were determined by adopting standard procedures. About 5 g of head rice was cooked in 50 ml of boiling distilled water taken in glass beakers that was immersed in boiling water bath. The following properties of cooked rice were then evaluated:

Volumetric expansion ratio

Volume of uncooked and cooked rice kernels was determined by toluene method [9] and the volumetric expansion ratio was calculated as:

$$\text{Volumetric expansion ratio} = \frac{\text{Vc}}{\text{Vuc}}$$

Where,
Vuc - Volume of uncooked rice kernels, ml
Vc - Volume of cooked rice kernels, ml

Water uptake ratio

Water uptake ratio of cooked rice was calculated using the following equation:

$$\text{Water uptake ratio} = \frac{\text{Wc} - \text{Wuc}}{\text{Wuc}}$$

Where,
Wuc - Weight of uncooked rice kernels, g
Wc - Weight of cooked rice kernels, g

Elongation ratio

Length of cooked and uncooked kernels were measured by using digital Vernier callipers and the elongation ratio was computed as:

$$\text{Elongation ratio} = \frac{\text{Xc}}{\text{Xuc}}$$

Where,
Xuc - Average length of 10 uncooked rice kernels, mm
Xc – Average length of 10 cooked rice kernels, mm

Solid loss

After cooking process was completed, the excess water was strained into a pre-weighed petri-dish and was kept in hot air oven at 105±1°C for about 24 h. After all the water was evaporated, the petri-dish with dried sample was cooled in a desiccator and weighed. An increase in weight of the petri dish was the solids leached during cooking and the solids loss was calculated as:

$$\text{Solids loss (\%)} = \left(\frac{\text{Weight of solids leached}}{\text{Weight of rice sample taken}}\right) \times 100$$

Cooking time

After 10 min of cooking, one rice kernel was taken out after every 30 s from the beaker and pressed between two glass plates. The disappearance of a chalky core indicated completion of cooking and the time (minutes) at which cooked rice showed absence of chalky core was reported as cooking time.

Whiteness index

Whiteness index of cooked rice gives a measure which correlates the visual ratings of whiteness for certain white and near white surfaces. The measurement is based on the CIE-LAB colour system using tristimulus colour values of L^*, a^* and b^*. The colour of cooked rice samples was measured by using Spectrophotometer (Make: Konica Minolta, Model: CM-5). The whiteness index was then determined using equation [10].

$$\text{Whiteness index} = 100 - \sqrt{(100 - L^*)^2 + (a^*)^2 + (b^*)^2}$$

Where,
L* - Lightness value
a* - Redness / Greenness value
b* - Yellowness / Blueness value

Gel consistency

Gel consistency of cooked rice was determined using the standard procedure [11].

Textural Properties of Cooked Rice

Texture Profile Analysis (TPA) of cooked rice kernels were carried out using a Texture Analyzer and the standard test recommended for such test by the manufacturer was followed to obtain various textural properties.

Hardness

Hardness of cooked rice is the peak force (N) of first compression (1f) in the TPA curve.

Stickiness

Stickiness of cooked rice is the peak force (N) below the zero force i.e, negative force (3f) in the TPA curve.

Cohesiveness

Cohesiveness was computed from the TPA curve as,
$\text{Cohesiveness} = A_2 / A_1$
Where,
A_1 - Area of TPA curve under first compression
A_2 - Area of TPA curve under second compression.

Adhesiveness

Adhesiveness (N.s) of cooked rice is the area under the curve due to adhesion i.e, negative area (A_3).

Results and Discussion

Characteristics of Freshly Harvested and Naturally Aged Paddy

The milling characteristics of paddy, both freshly harvested and naturally aged (for 6 months), and the physico-chemical and textural properties of their cooked rice samples are presented in Table 1. Though the milling yield was almost same for fresh and aged paddy, the head yield was considerably higher with naturally aged paddy (98.27%) when compared to fresh paddy (93.11%). Consequently, the breakage of rice was obviously lower with aged paddy. When the physico-chemical characteristics of cooked rice was considered, it could be seen that the volumetric expansion ratio (2.60), water uptake ratio (3.05), elongation ratio (1.56) and cooking time (25 min) were markedly higher; and solid loss (4.23%) and gel consistency (28.50 mm) were desirably lower, in case of rice from aged paddy when compared to fresh paddy. Further, the stickiness and adhesiveness of cooked kernels of aged paddy were observed to be less.

Table 1: Milling characteristics of freshly harvested and naturally aged paddy and physico-chemical and textural properties of their cooked rice

Property	Freshly Harvested Paddy	Naturally Aged paddy
Milling characteristics of paddy		
Milling Yield (%)	77.61	77.00
Head Yield (%)	93.11	98.27
Breakage (%)	6.89	1.73
Physico-chemical properties of cooked rice		
Volume Expansion Ratio	2.27	2.60
Water Uptake Ratio	2.55	3.05
Elongation Ratio	1.45	1.56
Solid Loss (%)	4.37	4.23
Cooking Time (min)	21.00	25.00
Whiteness Index	72.47	71.01
Gel Consistency (mm)	32.00	28.50
Textural properties of cooked rice		
Hardness (N)	3.5765	4.9342
Stickiness (N)	-0.4913	-0.2598
Cohesiveness	0.1082	0.1479
Adhesiveness (N.s)	-0.1587	-0.1116

Characteristics of Hydrothermally Treated Paddy for Accelerated Ageing

Milling characteristics

The results of milling trials of different hydrothermally treated paddy samples are presented in Fig. 1. It was generally observed that with severity of hydrothermal treatments, there was a continuous improvement in milling characteristics of paddy.

Milling yield

The effect of hydrothermal treatments on milling yield is shown in Fig. 1. It was found that for the wet steamed paddy samples, the milling yield varied from 78.10-75.68%. The maximum value of milling yield of 78.10% observed at steam pressure (gauge pressure) of 0.5 kg/cm^2 for and for the steaming duration of 10 min and the minimum value of milling yield was 75.68% observed at steam pressure of 0.0 kg/cm^2 for 5 min of steaming.

Head yield

Fig. 1 shows the effect of hydrothermal treatments on head yield. The maximum head yield (96.57%) was observed with paddy steamed at 0.5 kg/cm^2 for 10 min and the minimum value of head yield (89.76%) was recorded with paddy steamed at steam pressure of 0.0 kg/cm^2 for 5 min.

Rice breakage

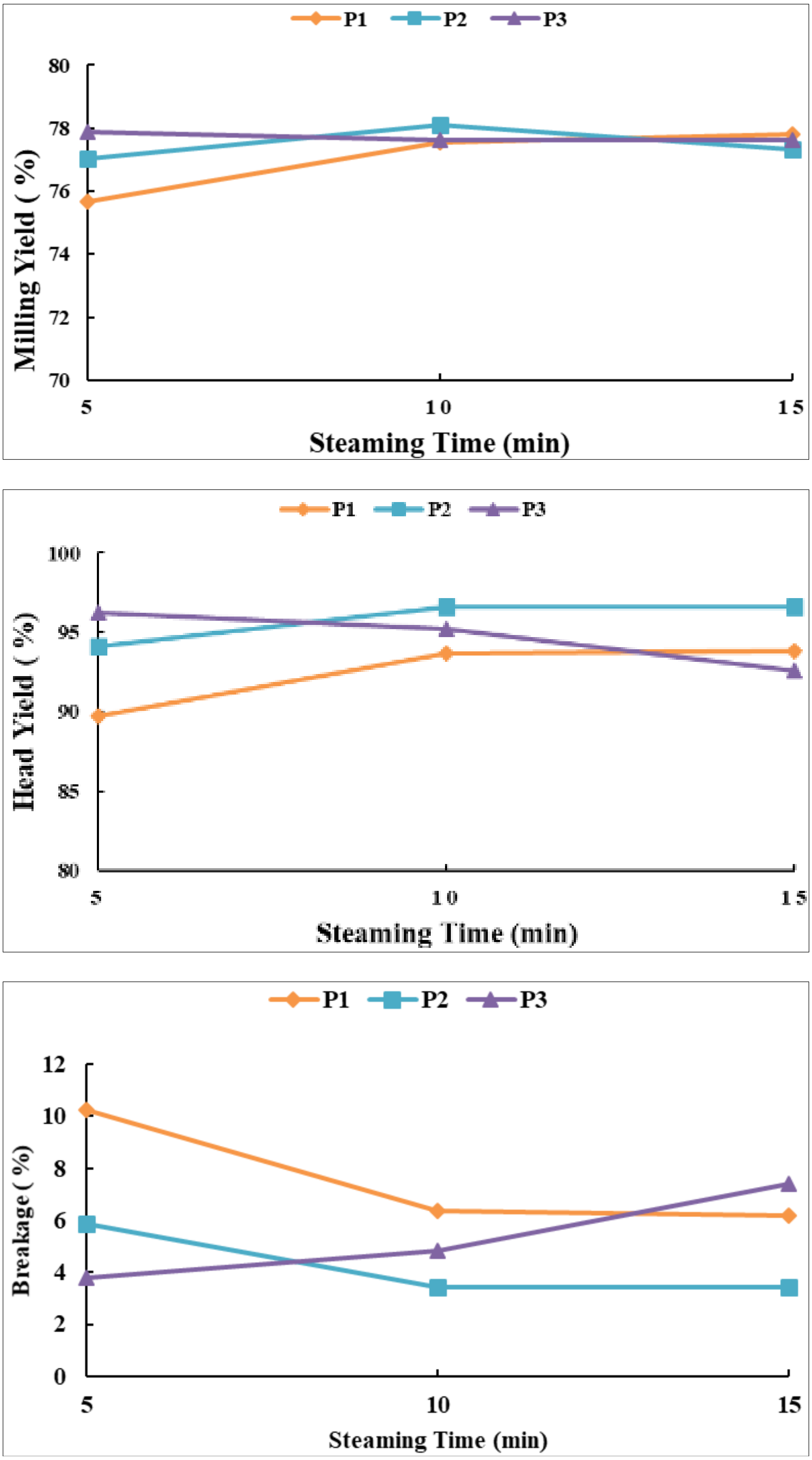
The effect of wet hydrothermal treatments on the rice breakage is shown in Fig. 1. The maximum value of breakage was usually observed at minimum value of head yield and vice versa. The maximum and minimum value of rice breakage recorded were 10.24 and 3.43% observed with paddy samples steamed at 0.0 kg/cm^2 for 5 minutes and 0.5 kg/cm^2 for 10 min, respectively.

Physico-chemical and cooking properties of milled rice

Physico-chemical and cooking properties of polished rice milled from hydrothermally treated paddy are presented below.

Volumetric expansion ratio

Table 2 shows the effect of ageing treatments of paddy on the volumetric expansion ratio of cooked rice. The mean volumetric expansion ratio of rice obtained from paddy steamed at different steam pressures (gauge) 0.0, 0.5 and 1.0 kg/cm^2 was 2.3103, 2.1662 and 2.2933, respectively; and the above values for different steaming times of 5, 10 and 15 min were 2.3038, 2.2437 and 2.2223, respectively. The volumetric expansion ratio increased from 2.27 for fresh rice to 2.6 recorded with rice obtained from naturally aged paddy at room temperature for six months. The volumetric expansion ratio of rice obtained from wet steamed paddy was not significant with respect to both steam pressure as well as steaming time. For aged paddy samples the volumetric expansion ratio was found to be more as compared to the freshly harvested paddy. Of all the wet steamed samples, the maximum volumetric expansion ratio was 2.58, observed at 0.0 kg/cm^2 of steam pressure for 5 min of steaming time.



Steam Pressure P_1 - 0.0, P_2 - 0.5, P_3 -1.0 kg/cm^2

Fig 1: Effect of wet steaming of paddy at different steam pressures on milling yield, head yield and breakage

Table 2: Effect of accelerated ageing treatments of paddy on volumetric expansion ratio of cooked rice

Steam Pressure (P) (kg/cm^2 - gauge)	Volumetric Expansion Ratio			Mean
	Steaming Time (S)			
	S_1 (5 min)	S_2 (10 min)	S_3 (15 min)	
P_1 (0.0)	2.580	2.200	2.151	2.3103
P_2 (0.5)	2.107	2.176	2.216	2.1662
P_3 (1.0)	2.225	2.355	2.300	2.2933
Mean	2.3038	2.2437	2.2223	2.2566

ANOVA			
Source	F-value	SE_m	CD @ 1%
P	NS	0.0785	-
S	NS	0.0785	-
P x S	NS	0.1360	-

Note: ** - Highly significant, NS - Non significant

Solid loss (%)

The effect of ageing treatments of paddy on the solid loss of cooked rice is shown in Table 3. The mean solid loss during cooking of rice from paddy samples treated using autoclave (wet steaming) at different steam pressures 0.0, 0.5 and 1.0 kg/cm^2 was 3.4210, 2.8787 and 2.9713%, respectively and the above values for different steaming times of 5, 10 and 15 min were 3.5477, 2.81 and 2.9133%, respectively. The solid loss of rice from freshly harvested paddy was 4.37% (Table 1) and that of naturally aged paddy it was 4.23%, which indicated that the leaching of solids during rice cooking will be reduced on ageing. The solid loss of rice from wet steamed paddy samples was significant with respect to the steam pressure as well as steaming time. Among all the wet steamed samples, the minimum solid loss was 2.354% in the rice obtained from paddy steamed at 1.0 kg/cm^2 of steam pressure for 10 min. This might be due to that the suitable wet heat treatment of the paddy prior to cooking reduced the pastiness of rice on cooking [12].

Table 3: Effect of accelerated ageing treatments of paddy on solid loss of cooked rice

Steam Pressure (P) (kg/cm^2 - gauge)	Solid Loss (%)			Mean
	Steaming Time (S)			
	S_1 (5 min)	S_2 (10 min)	S_3 (15 min)	
P_1 (0.0)	3.6300	3.2250	3.4080	3.4210
P_2 (0.5)	3.1370	2.8510	2.6480	2.8787
P_3 (1.0)	3.8760	2.3540	2.6840	2.9713
Mean	3.5477	2.8100	2.9133	3.0903

ANOVA			
Source	F-value	SE_m	CD @ 1%
P	**	0.0626	0.2875
S	**	0.0626	0.2875
P x S	**	0.1084	0.4980

Note: ** - Highly significant, NS - Non significant

Water uptake ratio

Among all the wet steamed samples, the maximum water uptake ratio was 3.294, observed for paddy steamed at 0.0 kg/cm^2 of steam pressure for 5 min. Water uptake of rice increased with increasing moisture content of conditioning before steaming. Increase in water uptake ratio of rice had also been determined [11, 13]. Expansion and water uptake are desirable economically for the food service industry as they lead to a fuller plate for the same amount of rice.

Elongation ratio

Of all the treated paddy samples, the maximum elongation ratio of rice was 1.464 observed in paddy steamed at 1.0 kg/cm^2 of steam pressure for 10 min. The elongation ratio was not significant with respect to wet steaming technique.

Cooking time

Among all treated paddy samples, the minimum cooking time was 19 min observed for paddy steamed at 0.5 kg/cm^2 of steam pressure for 15 min. Cooking time of wet steamed paddy was minimum compared to other accelerated ageing techniques as well as naturally aged paddy. This may be due to soaking of paddy prior to steaming, which reduces the cooking time. Cooking time of wet steamed samples was significant with respect to steaming time of paddy.

Whiteness index

Of all the wet steamed samples, the maximum whiteness index of rice was 70.791 observed for paddy steamed at 0.5 kg/cm^2 of steam pressure for 10 min. The whiteness index of wet steamed samples was not significant with respect to both steam pressure as well as steaming time.

Gel consistency

Of all the wet steamed samples, the minimum gel consistency was 27, observed for paddy steamed at 0.0 kg/cm^2 of steam pressure for 5 min. The gel consistency was not significant with respect to process parameters of wet steaming technique.

Textural properties of cooked rice

Effect of accelerated ageing treatments of paddy on the textural properties of cooked rice was given from Table 4 to 7. Generally, accelerated ageing lead to an increase in the hardness of rice. This may be attributed to the filling up of air spaces and fissures in the rice due to starch gelatinization. Hardness increased with increasing moisture content due to increased starch gelatinization [5]. Cohesiveness is the extent to which a sample tends to retain its shape (texture) after compression. The increased gelatinization of the starch may be responsible in increasing the cohesiveness (Fig. 2). Cooked aged rice was harder and less sticky than cooked freshly harvested rice, as measured by texturometer [14]. Short-time steaming of rough rice was also effective in reducing the stickiness of cooked, treated and milled rice [15].

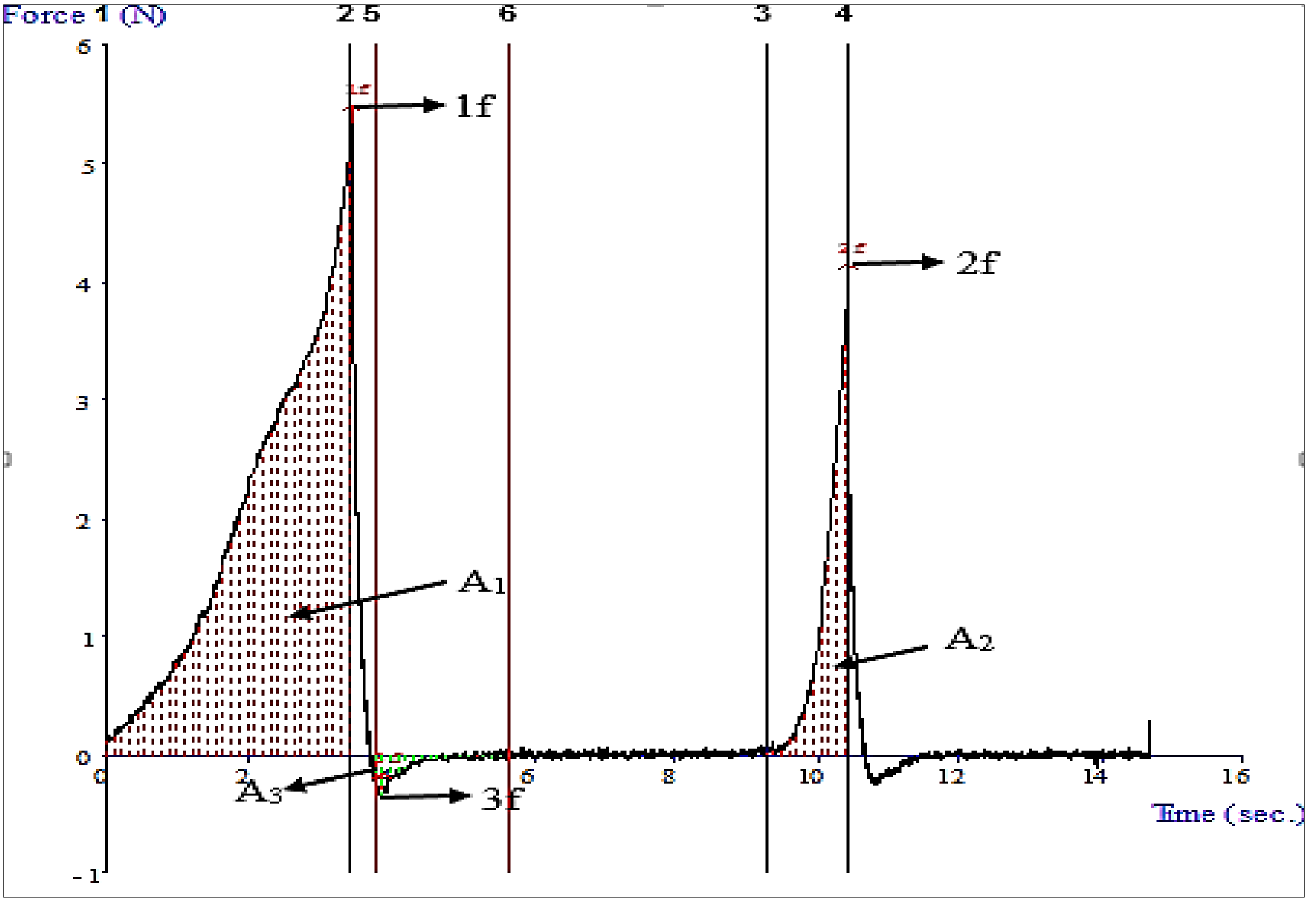


Fig 2: Texture profile analysis of cooked rice

Table 4: Effect of accelerated ageing treatments of paddy on the hardness of resultant cooked rice

Steam Pressure (P) (kg/cm^2 - gauge)	Hardness (N)			
	Steaming Time (S)			Mean
	S_1 (5 min)	S_2 (10 min)	S_3 (15 min)	
P_1 (0.0)	14.275	15.8767	18.3033	16.1517
P_2 (0.5)	12.455	11.2933	14.4633	12.7372
P_3 (1.0)	17.2717	15.0767	19.0917	17.1467
Mean	14.6672	14.0822	17.2861	15.3452

Table 5: Effect of accelerated ageing treatments of paddy on the stickiness of resultant cooked rice

Steam Pressure (P) (kg/cm^2 - gauge)	Stickiness (N)			
	Steaming Time (S)			Mean
	S_1 (5 min)	S_2 (10 min)	S_3 (15 min)	
P_1 (0.0)	-0.425	-0.3217	-0.2717	-0.3395
P_2 (0.5)	-0.2667	-0.165	-0.1833	-0.205
P_3 (1.0)	-0.04	-0.02	-0.05	-0.0367
Mean	-0.2439	-0.1689	-0.1683	-0.1937

Table 6: Effect of accelerated ageing treatments of paddy on the cohesiveness of resultant cooked rice

Steam Pressure (P) (kg/cm^2 - gauge)	Cohesiveness			
	Steaming Time (S)			Mean
	S_1 (5 min)	S_2 (10 min)	S_3 (15 min)	
P_1 (0.0)	0.1688	0.1611	0.1651	0.1650
P_2 (0.5)	0.1885	0.1686	0.1728	0.1766
P_3 (1.0)	0.1578	0.179	0.1513	0.1627
Mean	0.1717	0.1695	0.163	0.1681

Table 7: Effect of accelerated ageing treatments of paddy on the adhesiveness of resultant cooked rice

Steam Pressure (P) (kg/cm^2 - gauge)	Adhesiveness (N.s)			
	Steaming Time (S)			Mean
	S_1 (5 min)	S_2 (10 min)	S_3 (15 min)	
P_1 (0.0)	-0.125	-0.0783	-0.2467	-0.15
P_2 (0.5)	-0.1133	-0.085	-0.2017	-0.1333
P_3 (1.0)	-0.03	-0.0233	-0.05	-0.0344
Mean	-0.0894	-0.0622	-0.1661	-0.1059

Conclusion

From this study, it was clear that wet steaming process enhanced the ageing process in paddy. The physico-chemical properties of cooked rice like water absorption and volumetric expansion increased markedly after accelerated ageing whereas solid loss and cooking time decreased. The textural properties of cooked rice like hardness and cohesiveness increased whereas stickiness and adhesiveness decreased.

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