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Optimization of Aging Time and Temperature for Four Malaysian Rice Cultivars

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Abstract: Aging is a process that can develop rice-cooking quality. Specially, it helps to increase kernel elongation rate during cooking time. We have aged four popular Malaysian rice cultivars in different time and temperature conditions and we have observed that maximum good kernel elongation ratio for Mahsuri and Mahsuri Mutant are 100 °C for 5 hours. In 9192, maximum kernel elongation ratio was observed at 110 °C with 5 hours and for putri it was 110 °C for 3 hours. In Mahsuri, proportionate change range was 0.03 to 0.23. So we can say that the degree of elongation of Mahsuri is poor to low. For Mahsuri Mutant proportionate change range was 0.33 to 0.65 and the degree of elongation Mahsuri Mutant can be graded grading as medium. Proportionate change range was observed 0.23 to 0.60 in 9192 and it is convenient to say that degree of elongation of 9192 is low to medium. Finally, in putri a very interesting observation was occurred. When it was treated at 90 °C the lowest proportionate change (0.40) was observed with 1 hour curing and highest (0.55) was with 3 hours curing. In 100 °C, maximum proportionate changed was observed (0.59) with 3 hours curing and lowest was observed (0.41) at 7 hours curing. At 110 °C, lowest proportionate change (0.75) was observed with 9 hours curing and maximum proportionate change was observed with 7 hours curing (0.90). So we can see at 90 and 100 °C with different curing time proportionate changes was in between 0.40 to 0.59 and the degree of elongation may consider as medium. But at 110 °C temperature we were surprised and observed that with all different temperatures the degree of elongation was high (Range 0.75-0.90). At this temperature (110 °C) Putri showed good kernel elongation ratio and high degree of elongation like the other Basmati type fine rice. Higher actual elongation is a desirable character for the consumers; the following results are the average of different curing time because our used grain size was not truly uniform (Mahsuri 5.0 mm - 5.5 mm, Mahsuri Mutant 6.2 mm - 6.75 mm, 9192 6.5 mm - 7.0 mm and Putri 6.5 mm - 7.0 mm). In this experiment we have also observed that variety, temperature and time significantly influence elongation ratio, Proportionate change and actual elongation. Variety time interaction, variety temperature interaction and variety temperature time interactions also significantly influenced these physical properties of rice kernel. Temperature time interaction does not significantly influence on elongation ratio, but this interaction influence proportionate change and actual elongation.

Key words: Ageing, actual elongation, elongation ratio and proportionate change, rice

Introduction

It is very simple to practice, through aging or storing rough rice for 3-4 month after harvest also affects grain quality. Higher total and head rice yields are obtained from aged rice (Perez and Juliono 1981, 1982; Villarial *et al.*, 1976). In addition, aged milled rice has higher volume expansion and water absorption and less dissolved solids on cooking, and the cooked grain is more flaky (Villarial *et al.*, 1976). Thus aged rices are preferred in testing for milling and cooking properties. The overall changes may depend on the rice variety, storing conditions and further treatment. While it is common knowledge that ageing of rice affects the eating quality (Banu *et al.*, 2002). Aged rice is preferred over freshly harvested rice consumers in tropical Asia, but disliked in countries where japonica rice is consumed. But generally, kernel elongation is measured as the length wise proportionate change. Chavan *et al.* (1977); Sarathe *et al.* (1986) and Sarkar *et al.* (1994) also followed this method and they observed kernel elongation ratio is in between 1.52 to 1.62 in different Basmati and Basmati type varieties. Any way, high volume expansion of cooking is still considered to be the good quality by working class people of Asia who do not care whether the expansion is lengthwise or crosswise. Urban people, on the other hand, prefer the varieties that expand more in length than in breath (Choudhury, 1979). Many like Sarathe *et al.* (1986) mentioned that cooking quality of rice is mainly determined by water uptake, volume expansion and kernel elongation. Different studies shows that aging is related with these mentioned three rice quality characters. In the present study we have tried to find out the more convenient time and temperature for maximum good elongation, proportionate change and actual kernel elongation of four popular Malaysian rice cultivars. Specially Mahsuri and Putri, which is very common daily life Malaysians.

Through these studies we have tried to understand the curing effect (through natural and artificial) on rice cooking qualities such as elongation ratio, proportionate change and actual elongation. For these researches we have used two very important Malaysian rice cultivars Mahsuri (medium coarse), Putri (single fine rice cultivar in Malaysia) and two promising lines of MARDI (Mahsuri derivatives; Mutant and 9192). Through these studies we want to optimize the aging time, temperature and conditions. So, the consumers use these techniques for their domestic use as well as the traders for their commercial use. The most important issue is Mahsuri is continuously using as a parental materials in crossing block for it's well adaptability in Malaysian agro-climatic conditions. Simultaneously Malaysian fine rice breeders should use Putri to develop further new fine rice variety. Additionally, 9191 and Mahsuri Mutant (sister lines) are performing great because of their good yield and linear elongating characters. So our optimized curing technique may use as breeding tools to screening early generation materials of these four varieties.

Materials and Methods

Materials: Polished white rice grain of the following Malaysia rice Cultivar/advance lines (developed by MARDI)

1.Putri (Q 50), 2. Mahsuri, 3. Mahsuri Mutant 4. NS 9192

Methods

Artificial aging: Three different temperatures (90, 100 and 110 °C) and five different times (1, 3, 5, 7 and 9 hour) were used to cure the rice samples of the mentioned four rice varieties. Each sample was taken in to Greiner 50 ml airtight and oven proof test tube. After aging samples were kept in room temperature for 1 hour for cooling and then opened and proceed for further work. A Memmert (Germany) oven was used for these aging activities.

Natural aging: Seeds of the 4 mentioned variety kept in airtight container at room temperature (around 28 °C) and every month kernel elongation ratio was measured. These observations were continued for a period of six months.

Measurement of elongation ratio, proportionate change and actual elongation: Ten measured (length and breath) aged grain of (3 temperature X 5 different time) = 15 different treatment were taken into 20 ml glass test tube and soaked it for 20 minutes with 5 ml of tap water. After soaking, the test tubes were put in to boil water for around 30 minutes. When the grains cooked properly test tubes were taken out from boiled water and removed the water inside the test tubes. After that cooked grain were kept on a glass sheet for few minutes to evaporate extra moisture and then measured the length and breath of the cooked grain. Measurements were done through a digital slide calipers. Kernel elongation ratio means the proportionate change of rice grain after cooking. But different research group define it in different way, such as Sood and Siddiq (1980) during measuring kernel elongation they want to consider both length and breath wise expansion of grain after cooking and they proposed the following formula to measure kernel elongation:

$$PC = \frac{L_F/B_F - L_O/B_O}{L_O/B_O}$$

Where, L_F, B_F: length and breadth respectively of the kernel after cooking; L_O, B_O: Length and breadth before cooking.

To measured lengthwise elongation ratio, 10 cooked kernels average length was divided by 10 precooked kernel average length. From 10 cooked kernel average length we minus average length of precooked length of the same grains and determined the actual elongation.

Results and Discussion

Kernel elongation ratio: Good elongation ratio was observed in Mahsuri varieties in all three different temperatures (1.54 -1.84). But highest elongation was observed at 90 and 100 °C with 5 hours curing. On the other hand in Mahsuri Mutant varieties, highest elongation ratio (2.30) was observed at 100 °C with 5 hours curing. So to determine the maximum good kernel elongation ratio for the single cross populations (Mahsuri/Mahsuri Mutant and Mahsuri Mutant/Mahsuri) 100 °C will be used for 5 hours.

In 9192, minimum kernel elongation ratio was observed at 100 °C with 1 hours and maximum kernel elongation ratio was observed at 110 °C with 5 and 7 hours respectively. If we look at the kernel elongation ratio of Mahsuri Mutant at 110 °C for 5 hours, it is almost nearer to the highest score (2.29). So it is suggested that 110 °C temperature with 5 hours curing can be used as good optimized aging temperature and time for the single cross Populations of 9192/Mahsuri Mutant. An interesting observation was observed in the recent MARDI released fine rice variety 'Putri', which is using as a check in our crossing block. When we considered 90 °C temperature it shows lowest elongation (1.64) at 1 hour and highest elongation at 3 hours (1.85). At 100 °C temperature it shows lowest elongation (1.54) with 9 hours curing and highest elongation with 3 hours curing

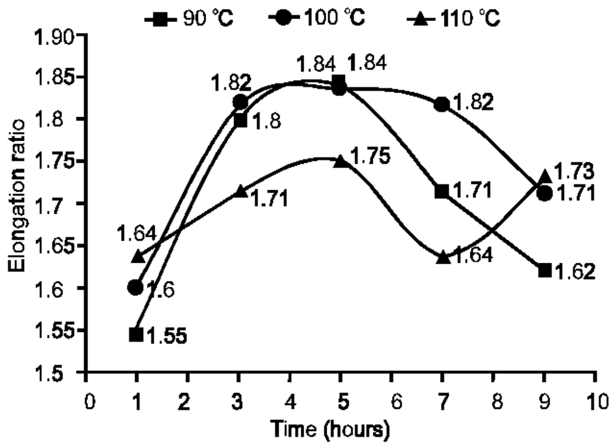

Fig. 1a: Elongation ratio of Mahsuri with five different aging times at three different temperature conditions

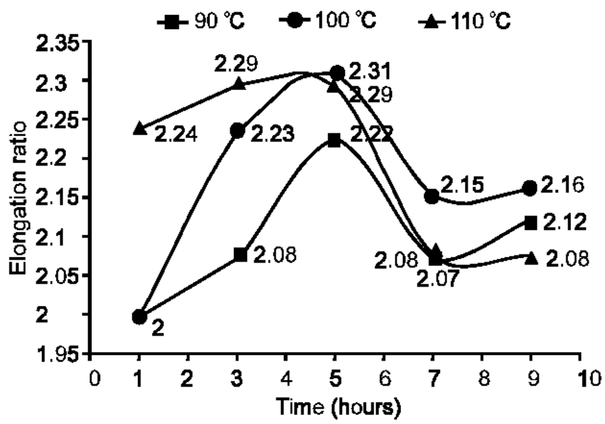

Fig. 1b: Elongation ratio of Mahsuri Mutant with five different aging times at three different temperature conditions

(1.9). Azeez and Shafi (1966) also suggested 100 °C with 3 hours aging is good for basmati type fine rice. But our observation is different to them because we found maximum good elongation at 110 °C and in all cases (1, 3, 5, 7 and 9 hours) the kernel elongation was more than 2. But the similarity is also at 3 hours we observed highest kernel elongation ratio 2.2, which is not significantly differ with other different times. Since we didn't find any literature that mentioned aging temperature could be use more than 110 °C, so we didn't proceed for further higher temperature. This is also not relevant our research objectives. But the trend was high kernel elongation ratio with high temperature for Putri.

Comparisons of elongation ratio of the parental materials at different temperatures conditions with different aging times: At 90 °C temperature condition all

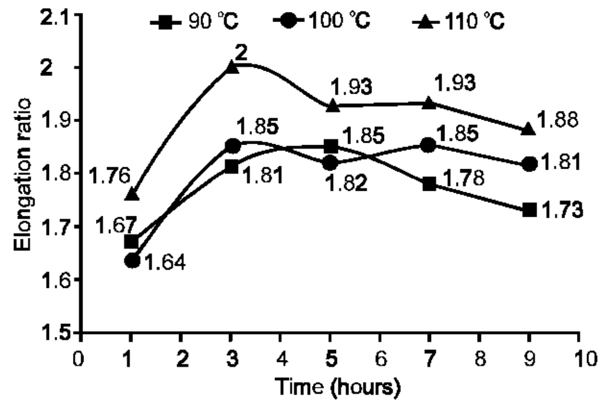

Fig. 1c: Elongation ratio of 9192 with five different aging times at three different temperature conditions

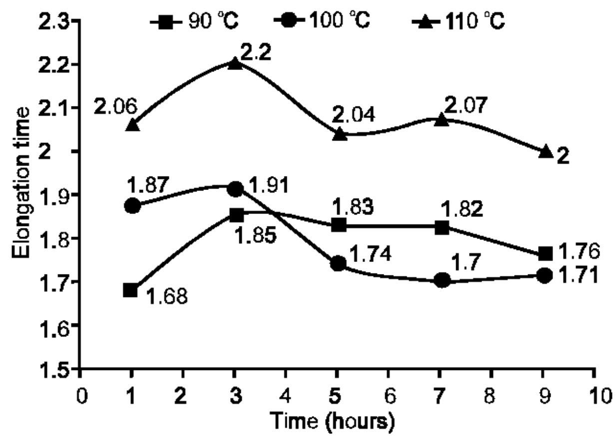

Fig. 1d: Elongation ratio of Putri (Q 50) with five different aging times at three different temperature conditions

the 4 varieties showed minimum kernel elongation ratio with 1 hour ageing time and all the four except Putri performed maximum elongation ration with 5 hours ageing time. Putri showed it (1.85) at 3 hours aging but at 5 hours it also show a good elongation ratio (1.84). So the from the observed results we can say that generally at 90 °C temperature condition 5 hours ageing is best for good kernel elongation for the selected parental materials. But it may consider 3 hours for fine rice like Putri. Details results of this 90 °C have displayed in Fig. 2a.

But at 100 °C temperature condition the scenario was bit changed, because here with 5 hours aging time only Mahsuri (1.84) and it's derivatives mutant line (Mahsuri Mutant) showed maximum elongation ratio (2.31). Again the Putri showed maximum elongation at 3 hours aging time (1.91) and here 9192 followed Putri that showed maximum elongation 1.85. But for lowest elongation all 4 varieties followed the previous trend that is with 1hour

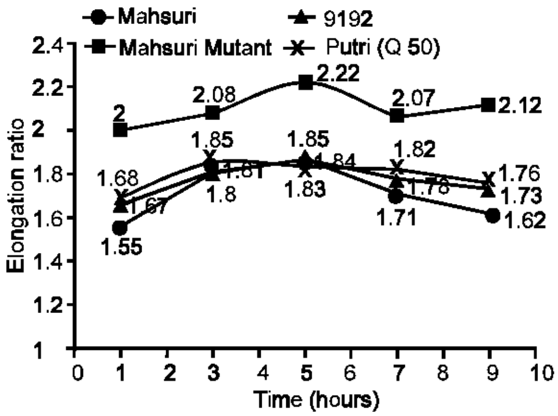

Fig. 2a: Comparison of elongation ratio of four rice varieties with five different ageing times at 90°C

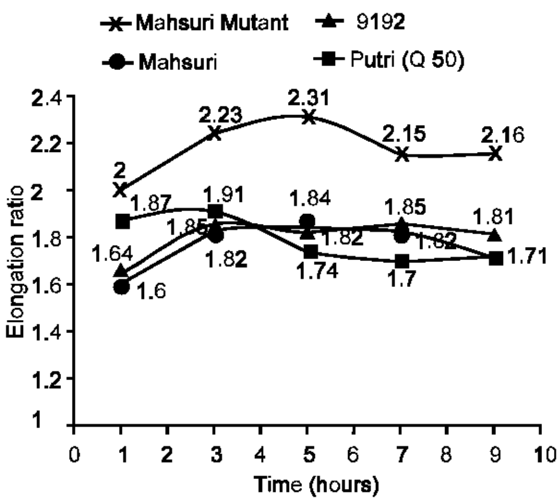

Fig. 2b: Comparison of elongation ratio of four rice varieties with five different ageing times at 100°C

ageing time. One more observation is elongation ratios have increased in all varieties at this 100 °C condition compare to 90 °C temperature condition. It may understand if we compare Fig. 2a and Fig. 2b.

The scenario was totally changed at 110 °C temperature condition because now all the four varieties showed maximum elongation ratio with 3 hours ageing time, though the mutant line (Mahsuri Mutant) follows it's previous trend and showed maximum elongation ratio (2.29) also with 5 hours aging time. But at initial stage (1 hour ageing time) all of them showed lowest elongation ratio. Details results is given in Fig. 2c. At this stage all the 4 varieties showed highest elongation ratio compare to the previous two temperature conditions. But of course we have observed at this stage cooked rice was not much flaky like at 100 °C and Mahsuri mutant showed breaking tendency. However, it is acceptable to

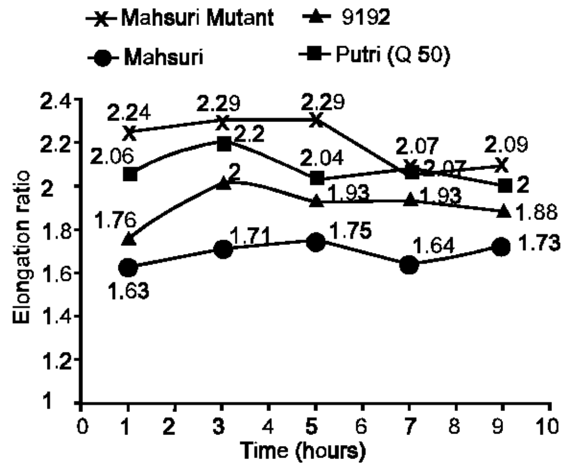

Fig. 2c: Comparison of elongation ratio of four rice varieties with five different ageing times at 110°C

the consumers. Putri showed more flakiness at this stage compare to others.

From the above results, we can conclude that to get a good elongation ratio for the parental materials (Mahsuri, Mahsuri Mutant, 9192) and the check variety (Putri), 110 °C with 3 hours ageing time is best and convenient

Proportionate change: In Mahsuri, when it was treated at 90 °C the lowest proportionate change (0.03) was observed with 1 hour curing and highest (0.23) was with 5 hours curing. In 100 °C, maximum proportionate changed was observed (0.30) with 7 hours curing and lowest was observed (0.14) at 1 hour curing. At 110 °C, lowest proportionate change (0.04) was observed with 1 hour curing and maximum proportionate change was observed with 9 hours curing (0.15). Within all 3 different temperatures with different time frames, in maximum cases it shows below 0 .10 proportionate changes and proportionate change range was 0.03 to 0.23. So according to Sood and Siddiq (1980) grading we can say that degree of elongation of Mahsuri is poor to low.

For Mahsuri Mutant, when it was treated at 90 °C the lowest proportionate change (0.48) was observed with 1 hour curing and highest (0.65) was with 5 hours curing. In 100 °C, maximum proportionate changed was observed (0.59) with 3 hours curing and lowest was observed (0.38) at 1 hour curing. At 110 °C, lowest proportionate change (0.33) was observed with 9 hours curing and maximum proportionate change was observed with 3 hours curing (0.59). Any way in all 3 different temperatures with different time frames and proportionate change range was 0.33 to 0.65. So for degree of elongation Mahsuri Mutant can be graded grading as medium.

When 9192 was treated at 90 °C the lowest

Table 1: Analysis of variance of elongation ratios, Proportionate changes and Actual elongations (through artificial aging) in different Varieties, Times and Temperatures

Source	Elongation ratio		Proportionate change		Actual elongation	
	DF	MS	DF	MS	DF	MS
Variety	3	1.43508**	3	1.75420**	3	104.929**
Temperature	2	0.34698**	2	0.12970**	2	12.0417**
Time	4	0.18200**	4	0.06596**	4	5.8999**
Variety*Temperature	6	0.10842**	6	0.20261**	6	4.4335**
Variety*Time	12	0.03139**	12	0.00932**	12	0.6508**
Temperature*Time	8	0.01209^{NS}	8	0.02504**	8	0.4013**
Variety*Temp*Time	24	0.01317*	24	0.01175**	24	0.3440*
Error	120	0.00839	120	0.00026**	120	0.1214**
	179		179		179	

***Highly significant at 0.01 level of probability, **Significant at 0.05 level of probability, NS = Non significant

proportionate change (0.23) was observed with 1 hour curing and highest (0.48) was with 5 hours curing. In 100 °C, maximum proportionate changed was observed (0.48) with 3 hours curing and lowest was observed (0.32) at 1 hour curing. At 110 °C, lowest proportionate change (0.38) was observed with 9 hours curing and maximum proportionate change was observed with 3 hours curing (0.60). Within all 3 different temperatures with different time frames, in maximum cases it shows proportionate changes with in the range of >0.30 -<0.55 and the actual proportionate change range was 0.23 to 0.60. So it is convenient to say that degree of elongation of 9192 is low to medium

A very interesting observation was occurred in case of Putri. When it was treated at 90 °C the lowest proportionate change (0.40) was observed with 1 hour curing and highest (0.55) was with 3 hours curing. In 100 °C, maximum proportionate changed was observed (0.59) with 3 hours curing and lowest was observed (0.41) at 7 hours curing. At 110 °C, lowest proportionate change (0.75) was observed with 9 hours curing and maximum proportionate change was observed with 7 hours curing (0.90). So we can see at 90 and 100 °C with different curing time proportionate changes was in between 0.40 to 0.59 and the degree of elongation may consider as medium. But at 110 °C temperature we were surprised and observed that with all different temperatures the degree of elongation was high (Range 0.75-0.90). Our previous observation of elongation ratio of Putri was also very high at 110 °C temperature. At this temperature (110 °C) Putri showed good kernel elongation ratio and high degree of elongation like the other Basmati type fine rice. Sood and Siddiq (1980) found degree of elongation in between this range in five basmati varieties. Chowdhury (1979) also observed kernel elongation ratio in between this range in 11 basmati type varieties.

Actual elongations: Higher actual elongation is a desirable character for the consumers; the following results are the average of different curing time because our used grain size was not truly uniform (Mahsuri 5.0 - 5.5 mm, Mahsuri Mutant 6.2 - 6.75 mm, 9192 6.5 - 7.0 mm and Putri 6.5 - 7.0 mm).

In Mahsuri, highest actual elongation was 4.6 mm at 100 °C and lowest was 3.0 mm at 90 °C. For Mahsuri Mutant it was 8.5 (highest) at 110 °C and 7 (lowest) at 90 °C. Highest (6.75) at 100 °C and lowest (4.35) at 110 °C actual elongation was observed in 9192. In Putri, highest actual elongation (8.1) was observed at 110 °C and lowest actual elongation (4.6) was observed at 90 °C. If we consider the whole results we can see lowest actual elongation was observed for all 4 varieties at 90 °C temperature, where is highest elongation was observed in all 4 varieties at 110 °C, so we can find a trend that actual elongation may related with higher temperatures. After that it is not using as a parameter to identify fine rice grain. Because not only elongation, but also the most desirable character for fine rice is elongation with flakiness. Majorie (2002) also reported with the reference of Bernas (Malaysia) that during the ageing period, the rice grain will elongate and aged rice will not be too soft when cooked.

Analysis the influencing factors and their interaction on kernel elongation, Proportionate change and actual elongation: In Table 1 we can observe that variety, temperature and time significantly influence elongation ratio, Proportionate change and actual elongation. Variety time interaction, variety temperature interaction and variety temperature time interactions also significantly influenced these physical properties of rice kernel. Temperature time interaction does not significantly influence on elongation ratio, but this interaction influence proportionate change and actual elongation.

Kernel expansions through natural aging: In the first month elongation ratio was observed 1.42, 1.71, 1.38 and 1.55 for the variety Mahsuri, Mahsuri Mutant, 9193 and Putri (Q 50) respectively. In the following months elongation ratio sometimes significantly and sometimes non-significantly increased. However, finally at 5 months it was significantly increased compare to the first months. Those were 1.64, 2.15, 1.57 and 2.08 for the variety Mahsuri, Mahsuri Mutant, 9193 and Putri (Q 50)

Table 1a: Kernel expansion of four Malaysian rice varieties with different conditions

Variety	Proportionate change			Actual elongation			Elongation ratio		
	Fresh	Natural Aged	Artificial Aged	Fresh	N. Aged	A. Aged	Fresh	N. Aged	A. Aged
Mahsuri	0.13	0.17	0.23	3.3	4.2	4.6	1.64	1.73	1.84
M. Mutant	0.41	0.43	0.65	4.30	7.50	8.50	1.77	2.15	2.30
9192	0.27	0.36	0.60	3.6	4.7	6.75	1.53	1.59	2.29
Putri	0.34	0.90	0.90	3.8	7.0	8.1	1.61	2.08	1.85

Highest observed values have used in all three conditions. A = Artificial, N = Natural

Table 1b: Correlation coefficient matrix between variety, Elongation ratio, Temperatures and Times (Artificial ageing)

	Temperature	Variety	Time	Elongation ratio
Temperature		0.000	0.000	0.289**
Variety			0.000	0.075^{NS}
Time				0.031^{NS}
Elongation ratio				

**= Correlation is significant at the 0.01 levels, NS= Not significant

Table 1c: Correlation coefficient matrix between variety, Proportionate change, Temperatures and Times (Artificial ageing)

	Temperature	Variety	Time	Proportionate change
Temperature		0.000	0.000	0.173**
Variety			0.000	0.711**
Time				0.018^{NS}
P. Change				

**= Correlation is significant at the 0.01 levels, NS= Not significant

Table 1d: Correlation coefficient matrix between variety, Actual elongation, Temperatures and Times (Artificial ageing)

	Temperature	Variety	Time	Actual elongation
Temperature		0.000	0.000	0.231**
Variety			0.000	0.325**.
Time				0.019^{NS}
Actual elongation				

**= Correlation is significant at the 0.01 levels, NS= Not significant

Table 1e: Correlation coefficient matrix between variety, Kernel Elongation, Temperatures and Times (Natural ageing)

	Elongation Ratio	Proportionate Change	Actual Elongation
Variety	0.121^{NS}	0.754**	0.283*
Month	0.535**	0.412**	0.471**

**= Correlation is significant at the 0.01 levels, *= Correlation is significant at the 0.05 levels, NS= Not significant

Table 1f: Correlation coefficient matrix between variety, kernel Elongation, Temperatures and times (without ageing))

	Elongation Ratio	Proportionate Change	Actual Elongation
Variety	-0.550**	0.443^{NS}	0.103^{NS}

**= Correlation is significant at the 0.01 levels, NS= Not significant

respectively. When we calculated the proportionate changes we observed in the first month for Mahsuri it was negative (-0.05), anyway it was increased at 0.09 at the 5th month. For Mahsuri Mutant it was started with 0.14 and reached up to 0.43 at 5th month. In first month 0.11 and 0.42 was observed for 9192 and Putri (Q 50) respectively. Those were changed into 0.26 and 0.90 at 5th months. For Mahsuri highest actual elongation (3.2) was observed at 4th and 5th month and highest actual elongation (3.7) also observed at 4th and 5th month for 9192. But for Mahsuri Mutant (7.5) and Putri (7.0) it was only observed in 5th month. Lowest actual elongation was observed in the first month in all four rice varieties and those were Mahsuri (2.1), Mahsuri Mutant (4.6), 9192 (2.5) and Putri (3.6).

Expansion observations in fresh kernels: When we used freshly harvested kernel to determine actual elongation, proportionate change and elongation ratio, then we can easily understand the effect of aging. From Table 1a we can get an idea of aging effect.

Determination of correlations: When we determined elongation ratio through artificial ageing we have observed significant correlations (0.289**) between elongation ration and different temperature conditions. Non-significant correlations were observed with variety (0.075) and times (0.031). In case of proportionate change significant correlations were observed with temperature (0.175**) and variety (0.711**), but with time it was not significant (Table 1c). In Table 1d, we can find that actual elongation shows significant correlations with temperature (0.231**) and variety (0.325**). Non-significant correlation was observed with time (0.019^{NS})

Additional observations

Discoloration/yellowing: We know that yellowing is caused by over-exposure of paddy to wet environmental conditions after harvest, and sometimes referred to as fermented grains or yellowed grain. It didn't happen for our used sample but during optimizing aging temperature yellowing was observed only in Mahsuri Mutant grains. It was observed in all treatments, but varying significantly from treatment to treatment. Lowest (1%) and very fin yellowing was observed at 90 °C, when it was cured for 1 hours and 3 hours respectively. Maximum and deep yellowing (15%) was observed at 110 °C when it was cured for 9 hours. When we cross sectioned these grain we found less crack compare to normal colored grain. The cooked grain also more flaky compare to normal colored grain, but cooked rice was not attractive, because of its light yellowish color.

Conclusion: "Aging the rice intensifies the aroma and taste even more" this a commercial statement of a basmati importer company (S & W) in England. Another company (Indo-European Foods, INC, 817 Elephant Brand Basmati Rice) is saying in their online message that they selling only aged basmati rice. They have added that the advantage of aging rice is that it loses most of its moisture. When it will cook, the rice grains reabsorb the moisture they had lost, and there fore grows over half an inch in length, releasing the beautiful aroma that it naturally possesses. Not necessary that through ageing, rice will grows over more than half inch, it is a statement of an advertisement, but also the reality is fine rice should elongate linear through ageing. Different research group Choudhury (1979), Juliono and Gonzales (1989) have observed this type of kernel elongation during cooking, they also found that ageing could improve fine rice cooking and eating quality. Though many factors are influencing rice cooking and eating quality, but it is already proven that aging is one of the most influencing to improve rice cooking and eating quality. Our observations also indicated the same thing. Additionally we have followed artificial aging technique, because it helped us to reduce time significantly and it is also less expensive compare to natural aging. Normand *et al.* (1964) also experimented the rice grain with heat treatment in closed containers and concluded that a temperature of 90 to 110 °C for two to eight hours produced rice similar to grain stored for fourteen months. Since we have optimized the proper aging method (time and temperature) for the parental materials, so we hope we will be able to screen our early generation materials through this optimized technique. This optimize curing technique may be use for commercial uses of these varieties.

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