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Influence of Rice Establishment Methods Affecting the Cooking Quality of Traditional Landraces in South India

Y. Nandhini[1], Subbalakshmi Lokanadhan[1], A. Christopher Lourduraj[2],
N. Thavaprakash[3], A. Ramalakshmi[4]

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ABSTRACT

Background: Rice is a staple food for half of the world population. Green revolution paved way for high yielding varieties and caused disappearance of traditional variety under cultivation. However, due to focus on nutritional benefits, the rice farmer's sight have returned towards cultivation of traditional landraces. To evaluate this, the present research aim to study the cooking quality of various landraces under different water saving establishment methods.

Methods: The field experiment was conducted during *Samba* 2021, in wetlands of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experiment was laid out in split plot design comprising four establishment methods as main plots *viz*. Aerobic rice (M_1), Puddled transplanting (M_2), Unpuddled transplanting (M_3), Direct seeded rice (M_4) with traditional landraces *viz*. *Karuppu kavuni* (V_1), *Mapillai samba* (V_2) and *Seeraga samba* (V_3) in sub plots.

Result: In this study physical characters like hulling and milling percentage, kernel length, breadth and length breadth ratio were analyzed along with the cooking qualities like kernel length and breadth after cooking, cooking time, linear elongation ratio, breadth expansion ratio, volume expansion ratio, solid loss, water absorption index and water solubility index. The puddled transplanting treatment recorded higher hulling and milling percentage of 4.5% and 5.8% than the aerobic rice cultivation. Among the landraces *mapillai samba* recorded kernel length and kernel breadth 8.20±0.06 mm and 2.78±0.02 mm respectively. The water absorption index and water solubility index was found to be higher in puddled transplanting treatment with 4.4% and 6.4% respectively than the aerobic rice treatment.

Key words: Cooking quality, Establishment methods, Physical characteristics, Traditional rice. landraces,

INTRODUCTION

Rice is a staple food for half of the world population. It is a major food crop consumed in the Asian continent. Rice is consumed in various forms by human since 8000 BC (Sweeney and McCouch, 2007). Two types of cultivated rice have been domesticated *i.e., Oryza sativa* and *Orzya glaberrima* in Asia and Africa. The Asian cultivated rice has genetic difference between them and they are listed as *japonica, indica* and *javanica* based on their growing locations (Kowsalya *et al.* 2022). Each cultivar is physiologically different and have various isoenzymes making a variety distinguished from others. Before the introduction of high yielding rice varieties, traditional rice genotypes were cultivated according to the region. *Kalanamak* a scented rice landrace is grown in Uttar Pradesh and in Wayanad (Kerala), *Mullan kaima* rice variety is grown which is specifically used for famous Malabar biryani making. Scented rice landraces like *gandhakasala* and *jeeragasala,* gives a heavenly fragrance which is also grown in Wayanad region (Blakeney *et al*. 2020). In Tamil Nadu region, the landrace *Paal Kudaivazhai* (in Tamil language "*Paal*" means "Milk") rice is given to lactating mothers (Balasubramanian *et al*. 2019).

Green revolution contributed highly for disappearance of traditional plant races. As of now, only few traditional varieties are Geographically Indicated (GI) (Eliazer *et al*. 2019). To preserve these varieties, storing of germplasm and seed alone is not sufficient but to cultivate them in a wide manner. Once the consumers are made aware of their nutritional benefits, there is a possibility of saving these varieties. American Chemical Society (ACS) specified that one spoonful of black rice (*Karuppu kavuni*) contains more anthocyanin antioxidants than a spoonful of blueberries. *Karuppu kavuni* has 18 amino acids, zinc that counts for immunity, iron that counts for carrying oxygen along with

[1]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[2]Directorate of Research, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[3]Regional Research Station, Virudhachalam-606 001, Tamil Nadu, India.
[4]Department of Microbiology, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

Corresponding Author: Y. Nandhini, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India. Email: yrnandhini1996@gmail.com

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copper, carotene, anthocyanin and several important vitamins (Mbanjo *et al*. 2020; Kowsalya *et al*. 2022). Our ancient healing text says, black rice helps to prevent cancer, diabetes and heart disease. Due to high fibre content, consuming just one third quantity is more than enough for fulfilling the day's requirement and to satiate the hunger. *Mappillai samba* rice is given to men to show their strength in lifting *ilavattakal* (Heavy spherical stones) in search of potential groom. It also improves digestion, regulates immune system, slows down ageing process and cures mouth ulcers. It also contains about 113 metabolites (Rajagopalan *et al*. 2022). *Seeraga samba* rice contains selenium, which helps to prevent the cancer of colon and intestine. It has got more fibre, which helps to remove free radicals from colon and intestine. Due to the low palmitic acid accumulation, *Seeraga samba* helps in preventing cardiovascular diseases and also it contains squalene, a triterpinoid compound having high potential for antibacterial, anticancer and immunostimulant activities (Ashokkumar *et al*. 2020).

The market value and the farmer's financial returns are determined by the characteristics of grain quality (Liu *et al*. 2022). Rice quality is an essential factor in consumer choice and demand. The quality of cooking is also considered when evaluating rice. Rice's economic worth in the market is based on how effectively it cooks and processes, which may be assessed using the ideal cooking time, water uptake ratio and grain elongation and swelling index (Oko *et al.* 2012).

Genetic background of the cultivars, environment and cultural practices have been shown to significantly affect composition of grain quality (Ravi *et al*. 2011). However, little is known regarding the influence of land establishment methods on traditional rice grain quality. Therefore the present investigation aims to study the effects of different establishment methods on some physical characteristics and cooking quality of rice varieties.

MATERIALS AND METHODS

The field experiment was conducted during *Samba* 2021, in wetlands of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu on Noyyal soil series (clay loamy, mixed isohyperthermic, Typic *Haplustalf*) belonging to *Alfisol* with clay loam texture and moderately alkaline with 8.2 pH. The available nitrogen in the soil was low, available phosphorus was medium and available potassium was high. For nutrient management, fertilizers are applied as per Crop Production Guide (CPG), 2012. The experiment was laid out in split plot design comprising four establishment methods as main plots *viz*. Aerobic rice (M_1), Puddled transplanting (M_2), Unpuddled transplanting (M_3), Direct seeded rice (M_4) and subplots with three traditional landraces *viz*. *Karuppu kavuni* (V_1), *Mapillai samba* (V_2) and *Seeraga samba* (V_3). After harvest, the rice grains were taken for hulling and milling, then seed grain were taken for measurement of physical characteristics and analysis of cooking quality.

Physical characteristics

Hulling percentage

Approximately 250 g of cleaned raw rice was hulled in experimental huller (rubber roller) with 14 per cent moisture content, separating husk and brown rice. The hulling percentage was calculated as suggested by Khan and Vikramanyake (1971).

$$\text{Hulling percentage} = \frac{\text{Weight of brown rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

Milling percentage

The brown rice that was obtained after hulling was subjected to milling, separating the milled rice and the bran. Then the percentage of milling was calculated as suggested by Khush *et al*. (1979).

$$\text{Hulling percentage} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

Kernel length and breadth

Kernel length and breadth were measured using a Vernier caliper and expressed in mm (Kaul, 1970).

Length breadth ratio

The grain shape was determined using length breadth ratio, the ratio between kernel length and kernel breadth (Kaul, 1970).

Cooking quality

Cooking time

Cooking time was calculated using the procedure followed by Chen *et al.* (2012). Selected traditional rice samples of 2 g is cooked in a test tube containing 20 ml of distilled water. Once the distilled water in the test tube reaches boiling point of 90°C, the rice grains were added. When the rice grains pressed between glass slides there should not be any white core. This shows that the rice grains were cooked well and the time taken is noted as the cooking time.

Kernel length after cooking (KLAC) and kernel breadth after cooking (KBAC)

For measuring the kernel length and breadth after cooking 25 rice kernels were pre-soaked in distilled water for 20 minutes and kept in a boiling water bath at 90°C and cooked until there is no white core while pressing between the glass slides. After cooling, the rice kernels was taken out for measuring the length and breadth and the average value was estimated (Pradhan *et al*. 2022).

Linear elongation ratio

Grain elongation ratio was calculated by measuring the length of rice before and after cooking according to Kerdpiboon and Charoendee, (2012).

Linear elongation ratio =

$$\frac{\text{Lenght of rice after cooking (mm)}}{\text{Lenght of rice befor cooking (mm)}}$$

Breadth expansion ratio

Breadth wise expansion ratio (BER) was calculated by measuring the brown rice breadth and the kernel breadth after cooking. Breadthwise expansion ratio calculated as suggested by Azeez and Shafi (1966).

Breadth expansion ratio =

$$\frac{\text{Breadth of rice after cooking (mm)}}{\text{Breadth of rice befor cooking (mm)}}$$

Volume expansion ratio

Volume expansion ratio was calculated using the method given by Prasert and Suwannaporn, (2009). 20 g of instant rice was taken in graduated cylinders by tapping 25-30 times to allow the grains to compact, then the sample cylinders were placed in microwave oven and cooked for 6 min and it calculated by the below given formula,

Volume expansion ratio =

$$\frac{\text{Volume of rice after cooking (ml)}}{\text{Volume of rice befor cooking (ml)}}$$

Solid loss

Solid loss is the cooking loss. It is calculated by placing 2 g of sample rice in a test tube with 20 ml distilled water and cooked. Then the solids left after cooking were collected and transferred to Erlenmeyer flask. The flask is kept in hot air oven at 110°C until the liquid evaporates and then cooled in a desiccator for 45 min. The final weight is noted down and the solid loss is calculated (Rosniyana *et al.* 2004).

Water absorption index (WAI)

WAI is calculated by using the method given by Yousf *et al.* (2017). It measures the volume occupied by the starch granule after swelling in water. Grounded rice sample of 1 g in each variety was suspended in 10 ml of distilled water at room temperature for 30 min and stirred. Consequently, the samples were centrifuged at 4000 rpm for 30 min. Then the weight of the sediments were noted. The formula for water absorption index is:

$$\text{Water absorption index} = \frac{\text{Weight of sediments}}{\text{Weight of dry solid}}$$

Water solubility index (WSI)

WSI determines the amount of polysaccharide release from the granule on adding excess amount of water. The supernatants from the WAI sample was poured into a petri dish of known weight and the residue was oven dried overnight at 70°C to take final weight. It is calculated by using the method given by Yousf *et al*. (2017). WSI is the dry weight of supernatant from the WAI expressed in percentage.

Water solubility index =

$$\frac{\text{Weight of dissoved solids in supernatant}}{\text{Weight of dry solid}}$$

RESULTS AND DISCUSSION

Hulling and Milling percentage

The results of hulling and milling percentage was calculated and depicted in Table 1. The hulling and milling percentage was significantly affected by the establishment methods of rice and the landraces. Among the rice establishment methods, the hulling and milling percentage was higher in puddled transplanting treatment (M_2) and lower percentage

Table 1: Hulling and milling percentage affected by establishment methods and varieties.

Treatment	Hulling %	Milling %
Establishment method		
M_1- Aerobic rice	76.80±1.96^c	70.03±1.66^c
M_2- Puddled transplanting	80.43±2.11^a	74.41±1.72^a
M_3- Unpuddled transplanting	79.60±1.81^{ab}	72.76±1.76^{ab}
M_4- Direct seeded rice	78.63±1.84^b	71.93±1.64^{bc}
SEd	0.63	0.83
CD (p=0.05)	1.55	2.04
Varieties		
V_1- *Karuppu kavuni*	75.13±0.77^b	69.73±0.87^c
V_2- *Mapillai samba*	79.95±0.80^a	71.65±0.93^b
V_3- *Seeraga samba*	81.53±0.81^a	75.49±0.94^a
Sed	0.75	0.59
CD (p=0.05)	1.59	1.25

The values are Mean±Standard error SE. The same letter in each column are not significantly different from each other based on LSD P≤0.05. Treatment details: M_1- Aerobic rice, M_2- Puddled transplanting, M_3- Unpuddled transplanting and M_4- Direct seeded rice (M_4); V_1 - *Karuppu kavuni*, V_2- *Mapillai samba* and V_3- *Seeraga samba.*

was observed in aerobic rice treatment (M_1). This might be due to lesser amount of water used for cultivation in aerobic rice whereas puddled field was maintained with adequate amount of water throughout the growing period. This was in accordance with Ali *et al*. (2012) and Zahra *et al*. (2022). On comparing the landraces, *Seeraga samba* (V_3) had higher hulling and milling percentage of 81.53 ± 0.81=% and 75.49 ± 0.94% followed by *Mapillai samba* with 79.95 ± 0.80% and 71.65±0.93% respectively. Kumari *et al*. (2020) also reported that *Seeraga samba* had higher hulling and milling percentage than *Karuppu kavuni* and *Mapillai samba* in their experiment for evaluating suitable rice varieties for organic farming.

Kernel length, breadth and length breadth ratio

Kernel length, breadth and length breadth ratio were significantly different and presented in Table 2. Puddled transplanting treatment (M_2) recorded longest kernel length, breadth and higher length breadth ratio with 5.36 ± 0.58 mm, 1.92 ± 0.09 mm and 2.77 ± 0.24 which is on par with unpuddled transplanting treatment (M_3) and the lowest was observed in aerobic rice treatment (M_1). Gewaily *et al*. (2019) also reported that more availability of water improved the kernel length, breadth and length breadth ratio of rice. *Karuppu kavuni* (V_1) recorded longest kernel length and breadth of 5.83±0.13 mm and 2.05±0.03 mm respectively and was in accordance with Ponnappan *et al*. (2017) who noted that *karuppu kavuni* recorded similar length, width and length breadth ratio.

KLAC and KBAC

There is a high significant difference of quality parameters with cooked rice among the establishment methods and the

Table 2: Kernel length (mm), kernel breadth (mm) and length breadth ratio affected by establishment methods and varieties.

Treatment	Kernel length (mm)	Kernel breadth (mm)	Length breadth ratio
Establishment method			
M_1- Aerobic rice	4.9±0.52[c]	1.85±0.07[b]	2.64±0.26[b]
M_2- Puddled transplanting	5.36±0.58[a]	1.92±0.09[a]	2.77±0.24[a]
M_3- Unpuddled transplanting	5.33±0.57[a]	1.91±0.09[a]	2.78±0.25[a]
M_4- Direct seeded rice	5.08±0.54[b]	1.85±0.07[b]	2.74±0.27[a]
SEd	0.06	0.01	0.02
CD (p=0.05)	0.17	0.03	0.06
Varieties			
V_1 - *Karuppu kavuni*	5.83±0.13[a]	2.05±0.03[a]	2.84±0.03[b]
V_2- *Mapillai samba*	5.62±0.12[b]	1.80±0.03[b]	3.11±0.03[a]
V_3- *Seeraga samba*	4.07±0.08[c]	1.81±0.00[b]	2.25±0.00[c]
SEd	0.05	0.01	0.03
CD (p=0.05)	0.10	0.03	0.07

The values are Mean±Standard error SE. The same letter in each column are not significantly different from each other based on LSD P≤0.05. Treatment details: M_1- Aerobic rice, M_2- Puddled transplanting, M_3- Unpuddled transplanting and M_4- Direct seeded rice (M_4); V_1 - *Karuppu kavuni*, V_2- *Mapillai samba* and V_3- *Seeraga samba.*

Table 3: Kernel length after cooking (mm) and kernel breadth after cooking (mm) affected by establishment methods and varieties.

Treatment	Kernel length after cooking (mm)	Kernel breadth after cooking (mm)
Establishment method		
M_1- Aerobic rice	7.20±0.71[b]	2.53±0.17[b]
M_2- Puddled transplanting	7.46±0.74[a]	2.63±0.17[a]
M_3- Unpuddled transplanting	7.43±0.72[a]	2.63±0.17[a]
M_4- Direct seeded rice	7.30±0.70[b]	2.63±0.17[a]
SEd	0.04	0.03
CD (p=0.05)	0.10	0.09
Varieties		
V_1 - *Karuppu kavuni*	7.93±0.09[b]	2.78±0.02[b]
V_2- *Mapillai samba*	8.20±0.06[a]	2.78±0.02[a]
V_3- *Seeraga samba*	5.93±0.05[c]	2.28±0.02[c]
SEd	0.10	0.03
CD (p=0.05)	0.21	0.07

The values are Mean±Standard error SE. The same letter in each column are not significantly different from each other based on LSD P≤0.05. Treatment details: M_1- Aerobic rice, M_2- Puddled transplanting, M_3- Unpuddled transplanting and M_4- Direct seeded rice (M_4); V_1 - *Karuppu kavuni*, V_2- *Mapillai samba* and V_3- *Seeraga samba* tested traditional landraces (Table 3). On comparing the different establishment methods KLAC and KBAC were found to be significantly higher in puddled transplanting treatment (M_2) with the values of 7.46±0.74 mm and 2.63±0.17 mm respectively as the kernel length and breadth before cooking were higher in the same puddled transplanting treatment. *Mapillai samba* (V_2) recorded longer kernel length and breadth of 8.20±0.06 mm and 2.78±0.02 mm respectively after cooking due to its higher water absorption index.

LER, BER and VER

LER, BER and VER were analyzed and given in Table 4. LER was found to be higher in aerobic rice (M_1) with value of 1.47±0.04 followed by direct seeded rice (M_4) but the VER was higher in puddled and unpuddled transplanting plots (M_2 and M_3) with the value of 2.50±0.23. This might be due to the greater KLAC and KBAC. While comparing the varieties, *Seeraga samba* (V_3) recorded significantly higher volume expansion ratio of 2.78±0.09 followed by *karuppu kavuni* (V_1). Because of the smaller grain size of *Seeraga samba* (V_3) comparing to the other two varieties, there will be more number of grains which lead to the higher VER.

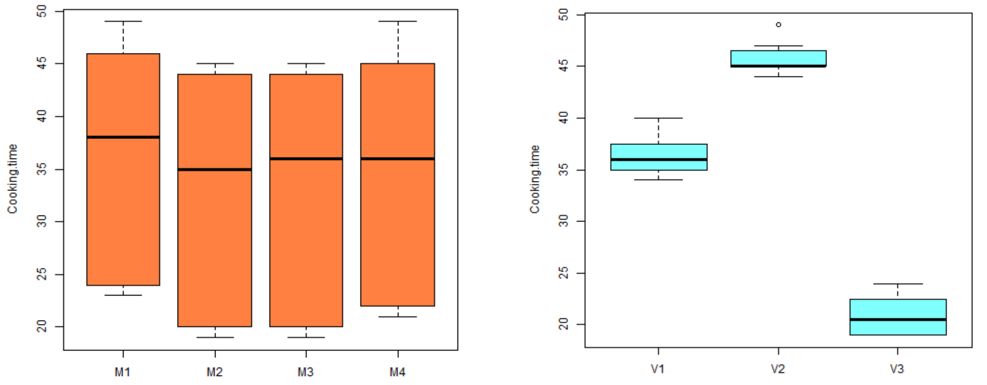
Cooking time

Fig 1a and 1b represents the cooking time of rice under different establishment methods with various traditional rice landraces. The cooking time is prolonged for about 11 mins in aerobic rice treatment (M_{-1}) than puddled transplanting treatment (M_2). Generally the flooded rice varieties have lower cooking time as in flood condition the kernels of rice become soft according to Pandey *et*

Table 4: Linear elongation ratio, breadth expansion ratio and volume expansion ratio affected by establishment methods and varieties.

Treatment	Linear elongation ratio	Breadth expansion ratio	Volume expansion ratio
Establishment method			
M_1- Aerobic rice	1.47±0.04[a]	1.36±0.09[b]	2.16±0.20[b]
M_2- Puddled transplanting	1.39±0.03[c]	1.36±0.07[b]	2.50±0.23[a]
M_3- Unpuddled transplanting	1.39±0.03[c]	1.37±0.08[b]	2.50±0.23[a]
M_4- Direct seeded rice	1.43±0.03[b]	1.42±0.09[a]	2.43±0.23[a]
SEd	0.01	0.01	0.03
CD (p=0.05)	0.03	0.03	0.07
Varieties			
V_1- *Karuppu kavuni*	1.36±0.02[b]	1.35±0.02[b]	2.43±0.07[b]
V_2- *Mapillai samba*	1.46±0.02[a]	1.54±0.02[a]	2.00±0.07[c]
V_3- *Seeraga samba*	1.46±0.02[a]	1.26±0.01[c]	2.78±0.09[a]
SEd	0.01	0.01	0.02
CD (p=0.05)	0.03	0.02	0.05

The values are Mean±Standard error SE. The same letter in each column are not significantly different from each other based on LSD P≤0.05. Treatment details: M_1- Aerobic rice, M_2- Puddled transplanting, M_3- Unpuddled transplanting and M_4- Direct seeded rice (M_4); V_1 - *Karuppu kavuni*, V_2- *Mapillai samba* and V_3- *Seeraga samba*.



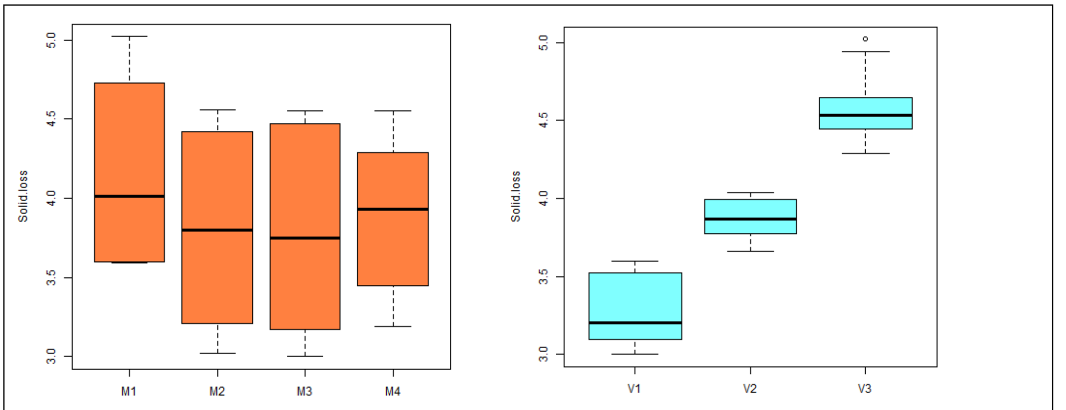
Treatment details: M_1- Aerobic rice, M_2- Puddled transplanting, M_3- Unpuddled transplanting and M_4- Direct seeded rice (M_4); V_1- *Karuppu kavuni*, V_2- *Mapillai samba* and V_3- *Seeraga samba*.

Fig 1a and 1b: Cooking time affected by establishment methods and varieties.

al. (2014). Shorter grain type *Seeraga samba* (V_3) recorded lower cooking time of 27 mins and higher cooking time of 61 mins was recorded in *Mapillai samba* (V_2). Shorter grain varieties have lower amylose content (Chumsri *et al*., 2021). The changes in amylose content between rice varieties may be the cause of the variation in cooking times (Bibi *et al*. 2011). The cooking time was very much increased in aerobic rice treatment because of longer time taken by grain to swell compared to other establishment methods. Due to the hardness of the *mapillai samba* landrace grain, it showed increased cooking time but values of WAI and WSI were higher.

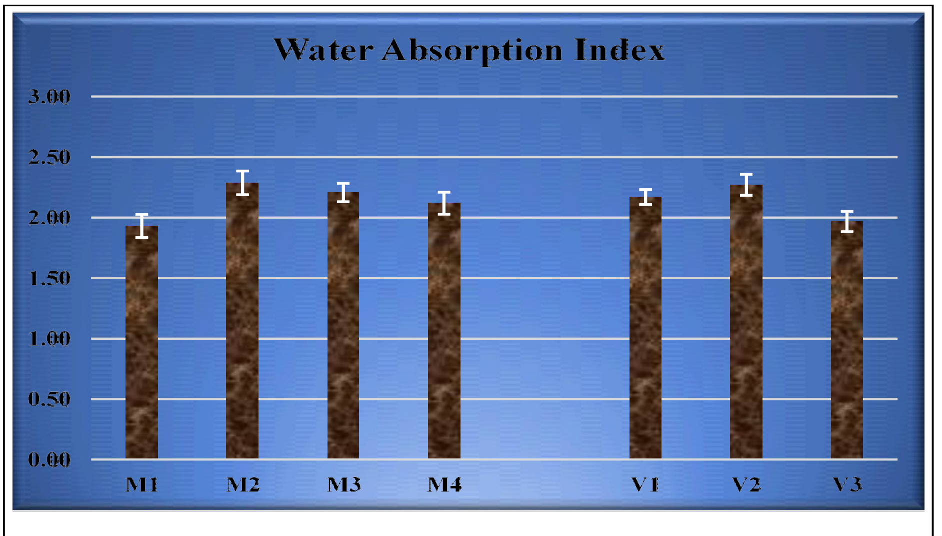
Solid loss

Solid loss is the amount of water that is left in the rice after cooking. From the Fig 2a and 2b, it was observed that the solid loss was less in puddled and unpuddled transplanting treatment (M_2 and M_3) with a minimum of 3.80±0.40% in both conditions and maximum solid loss of 4.16±0.38% was observed in aerobic rice treatment (M_1). *Karuppu kavuni* (V_1)



Treatment details: M_1 - Aerobic rice, M_2 - Puddled transplanting, M_3 - Unpuddled transplanting and M_4 - Direct seeded rice (M_4); V_1 - *Karuppu kavuni*, V_2 - *Mapillai samba* and V_3 - *Seeraga samba*.

Fig 2a and 2b: Solid loss affected by establishment methods and varieties.



Treatment details: M_1- Aerobic rice, M_2- Puddled transplanting, M_3- Unpuddled transplanting and M_4- Direct seeded rice (M_4); V_1- *Karuppu kavuni*, V_2- *Mapillai samba* and V_3 - *Seeraga samba*

Fig 3: WAI affected by establishment methods and varieties.

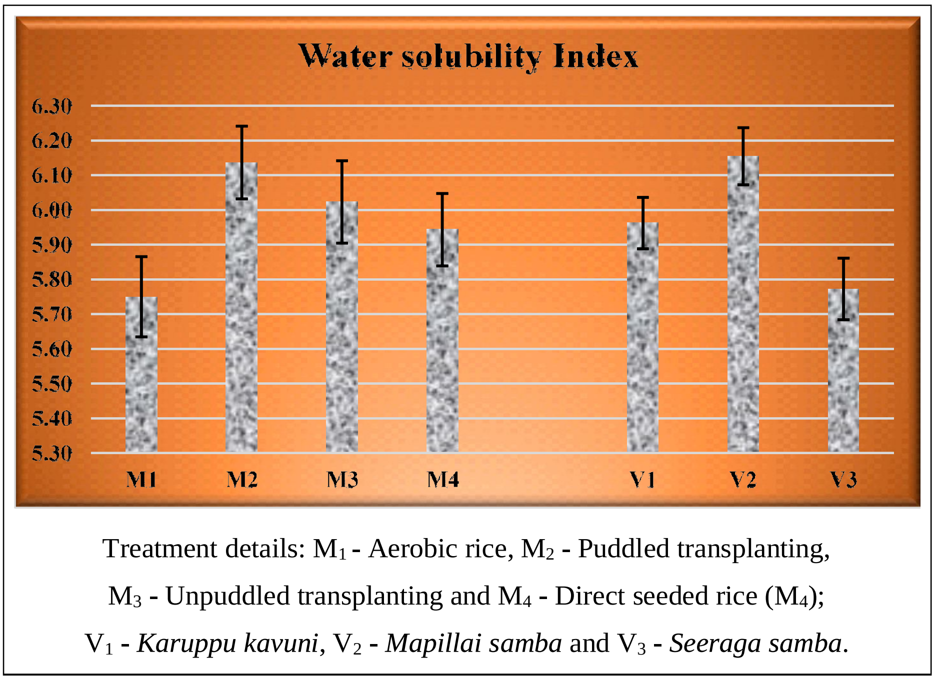


Fig 4: WSI affected by establishment methods and varieties.

recorded lower solid loss 3.28±0.12% followed by *Mapillai samba* (V_2) (3.88±0.05%). This indicates that the water absorption was better in puddled transplanting (M_2) and the pigmented rice varieties *viz. Karuppu Kavuni* (V_1) and *Mapillai samba* (V_2) (Devraj *et al.* 2020).

Water absorption index (WAI)

WAI is the measurement of volume of starch occupied to form a gel after swelling in water. This is dependent on the availability of hydrophilic groups and their ability to help form the gel. The WAI were analyzed and presented in Fig 3. It denotes that water absorption index significantly differed among the establishment methods with the highest value of 2.28±0.10 g/g recorded in puddled transplanting treatment (M_2). In landraces, *Mapillai samba* (V_2) recorded the highest value of 2.27±0.09 g/g followed by *Karuppu kavuni* (V_1) with 2.17±0.06 g/g. This variation in WAI may result from differences in the number of OH groups that are used to generate covalent and hydrogen bonds between the chains of starch, as well as from the loss of the crystalline structure of the starch (Gunaratne and Hoover, 2002).

Water solubility index (WSI)

WSI represents the number of starch particles distributed with the number of water-soluble molecules. The WSI were analyzed and depicted in Fig 4. There was a significant difference among the establishment methods and between varieties on WSI. Puddled transplanting treatment (M_2) recorded the highest water solubility index of 6.13±0.10 g/g followed by unpuddled transplanting treatment (M_3) with 6.02±0.12 g/g. In traditional landraces, *Mapillai samba* (V_2) significantly recorded the highest WSI of 6.16±0.08 g/g and lower WSI of 5.77±0.09 g/g was noted in *Seeraga samba* (V_3). The development of semi-crystalline structure and fragmentation of starch granules may be the cause of the variance in WSI amongst the different rice types (Eliasson, 2017).

CONCLUSION

Based on the above study, it can be concluded that different establishment methods of rice had significant influence on physical characteristics and cooking quality of traditional rice varieties. Low water availability in aerobic rice treatment reduced the hulling percentage, milling percentage, kernel length and breadth of rice whereas puddled and unpuddled transplanting treatment of all the three traditional varieties had better cooking quality followed by direct seeded rice treatment. As VER is an important cooking parameter, *karuppu kavuni* landrace performed better in the aerobic cultivation and it can be opted for planting in aerobic establishment method. All the landraces tested *viz. Karuppu kavuni, Mapillai samba* and *Seeraga samba* performed well in puddled transplanting establishment method.

Conflict of interest: None.

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