RESEARCH ARTICLE

A STUDY ON CHANGES IN AMYLOSE AND RESISTANT STARCH CONTENTS OF SELECTED RICE VARIETIES BY TRADITIONAL COOKING METHODS

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ABSTRACT

Resistant starch (RS) is considered to possess several health benefits. The amylose, RS and their relative changes with Total Starch (TS) in different varieties of rice from Northern Sri Lanka with the different traditional cooking methods were determined. For this study seven each of traditional and improved rice varieties were selected. In order to find the effects of traditional cooking methods, three traditional and two improved rice varieties were selected. Traditional rice variety *Thattu Wee*, contained the highest RS content. Different cooking methods reduced the RS contents of all the selected rice samples. The traditional rice variety *Moddakaruppan*, lost the highest amylose content except when pre-soaked and cooked without excess water while cooking with and without excess water led to a decrease in amylose related to TS contents except in *Periyavellai.* Variation in RS related to TS contents showed different changes with cooking methods and rice varieties. RS related to amylose contents decreased by cooking with and without excess water, except in Bw351 cooked without excess water (where there was no change) and with roasting, while pre-soaking and cooking without excess water increased the contents. Among the three traditional rice varieties selected for cooking, *Periyavellai* lost the least amounts of amylose and RS but the loss was more than that of Bw351.

Keywords: Amylose, Resistant starch, Rice, Sri Lankan rice varieties, Total starch

INTRODUCTION

Rice is the staple food of half of the world's population and is widely consumed in Asian countries as well as in Sri Lanka (FAO Report 2019). Starch in rice is the major source of energy (Juansan *et al*. 2012) and there are different types of starch namely rapidly digestible starch (RDS), slowly digestible starch (SDS) and RS depending on the rate of digestion (Englyst *et al*. 1992). Different studies were carried out to improve the health benefits of Sri Lankan rice varieties (Hettiarachchi 2013).

RS is considered as a functional carbohydrate and is said to be 30% of the fibre content of foods (Englyst *et al*. 1989). The starch, which cannot be digested by the carbohydrases enzyme of the human digestive system, are known as RS. The RS is defined as the starch and its derivative products that escape the normal digestion route would undergo fermentation by the intestinal microbial flora and get fermented to chain fatty acids (SCFA) such as acetic acid, butyric acid and propionic acid. Resistant starch is classified in to four types (Englyst *et al*. 1989; Englyst *et al*. 1992; Nugent 2005) and recently the fifth type has been included. Thus, RS is classified into five subtypes, namely RS1, RS2, RS3, RS4 and RS5 (Sajilata *et al*. 2006).

RS is considered a type of dietary fiber and increase consumption of RS is associated with variety of health benefits. RS improves blood glucose and insulin responses and promotes body fat utilization. The RS is considered as

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the functional food and provides health benefits such as preventing and reducing metabolic syndrome (Knowler *et al*. 2002 Hasler and Brown 2009; Wahjuningsih *et al*. 2018), colon cancer (Zhang and Hamaker 2010), obesity and weight management (Swinburn *et al*. 2009; Wanders *et al*. 2011). Recent health statistics of the Sri Lankan population have shown rising incidences of non-communicable diseases mainly due to dietary habits (Katulanda *et al*. 2010).

There are about 55 varieties of rice recommended for cultivation by the Department of Agriculture, Sri Lanka (RRDI 2019). RS contents of about 38 Sri Lankan rice varieties were reported (Abeysekera *et al*. 2018). Since the rice varieties preferentially consumed in the Northern part of Sri Lanka are different from the other parts of Sri Lanka, the rice varieties commonly consumed in the Northern part of Sri Lanka were selected for this study and the RS contents were estimated. Then among the selected fourteen varieties of the traditional and improved rice varieties, three traditional and two improved rice varieties were selected for the study. The aim present study aimed to compare the composition of the selected rice varieties for total starch, amylose, resistant starch, amylose and resistant starch related to total starch content and their changes under different traditional cooking conditions.

MATERIALS AND METHODS

Fourteen rice varieties grown in the Northern Province, were obtained from Rice Research Development Institute, Paranthan, Northern Province, Sri Lanka (Table 1). Among them seven of each were traditional and improved varieties. For this study, the paddy samples collected were one year old. Enzymes, Amyloglucosidase (modified strain of the *Aspergillus niger*, Activity 3300 U/mL; Batch No A9913) and pancreatic α-amylase (a modified strain of *Bacillus licheniformis*, Activity 2900U/mL; Batch No 10070) were purchased from Sigma Chemical Company, USA.

All the paddy samples were de-husked with a Dehuller (TM05C, Sataki, Japan). The length of the rice samples was measured with a

Table 1: Colours of the pericarp and, the lengths and amylose contents of the different traditional and improved varieties of raw rice.

Variety	Name	Pericarp colour	Average length (mm)	Grain Size	Amylose content (%)
Traditional	*Kallundaai*	Red	5.3 ±0.2	Short	24.3 ±0.5
	Moddakaruppan	Red	5.1 ±0.5	Short	27.2 ±0.2
	Murungakayan	Red	5.1 ±0.2	Short	26.3 ±0.9
	Pachchaperumal	Red	5.9 ±0.6	Medium	27.9 ±0.7
	Periyavellai	Red	5.7 ±0.8	Medium	28.6 ±0.9
	Suwandal	White	5.0 ±0.2	Short	22.1 ±0.5
	Thattu Wee	Red	5.2 ±0.5	Short	23.1 ±0.5
Improved	*At362*	Red	6.5 ±0.8	Medium	24.1 ±0.5
	Bg250	White	7.2 ±0.5	Long	23.3 ±0.8
	Bg361	Red	5.2 ±0.8	Short	26.1 ±0.5
	Bg366	White	5.7 ±0.4	Medium	21.5 ±1.0
	Bw351	Red	5.4 ±0.6	Short	27.4 ±0.5
	Ld356	Red	4.9 ±0.9	Short	23.5 ±0.3
	Ld365	Red	5.0 ±0.5	Short	24.2 ±0.9

Mean of values ±SD. (standard deviation) (n=3). All results are given on dry weight basis.
Size Category:
Very long - More than 7.5mm; Long - 6.61 to 7.5mm; Medium - 5.51 to 6.6mm and Short- less than 5.5mm (Juliano, 1993).

Venire Calliper. The moisture content of rice was determined by the oven-dry method (AOAC 2000). Resistant starch and non-resistant starch were determined by the procedure developed by McCleary and Monaghan (2002). The starch was acid hydrolyzed (Pearson, 1976) and the reducing sugar was estimated by the DNS method (Miller 1959). The amylose content of rice was determined by the method described by Juliano (1971).

Among the fourteen rice varieties, three traditional and two improved rice verities preferentially consumed in the Northern Province were selected and cooked by different traditional methods commonly practiced.

Cooking without excess water

The selected raw rice varieties to water ratios were calculated by pre-testing the amounts. The traditional and improved rice varieties were cooked with water by taking the rice to water in the ratios varying from 1:5 to 1:12. Then the optimized ratios were determined as 1:10 (w/v) for traditional and 1:9 (w/v) for improved rice varieties. The selected traditional and improved rice samples (10 g) were cooked with pre-determined amounts of water. The remaining water retained with the rice was evaporated by keeping the cooked rice in low flame.

Pre-soaking and cooking without excess water

The rice samples were soaked in tap water (Rice: Water ratio was 1:20, w/v) at room temperature for 3 hours. The selected raw rice varieties to water ratios were calculated by pre-testing the amounts. The traditional and improved rice varieties which were pre-soaked in tap water and cooked with water by taking the soaked rice to water in the ratios varying from 1:3 to 1:10. Then the optimized soaked Rice to Water ratios were determined as 1:8 (w/v) for traditional and 1:7.5 (w/v) for improved rice varieties. The selected traditional and improved rice varieties were cooked with the pre-determined amounts of water. The water retained with the rice was evaporated by keeping the cooked rice in low flame.

Cooking with excess water

The washed rice varieties (10g) were cooked with excess water (200mL). After cooking the excess water was decanted. The water retained with the rice was evaporated by keeping the cooked rice in low flame.

Roasting of selected rice samples

The rice samples were roasted by heating in a dry pan until the rice became golden brown with frequent mixing with the aid of a wooden spoon (traditional roasting method) under low flame.

Analysis of the cooked rice samples

Raw and roasted rice samples were ground to a fine powder using a laboratory miller and sieved (mesh size 0.5mm). The amylose, TS, RS and moisture contents were estimated. After cooking and cooling, the cooked rice samples were minced with a domestic grinder into a paste and analyzed for the amylose, TS, RS and moisture contents.

Statistical analysis

All the experiments were performed in triplicates. Result were expressed with the means and standard deviations. Regression analysis was performed with MS Excel 2013. Significant differences were estimated with 95% Confidence Interval ($p<0.05$).

RESULT AND DISCUSSION

There are about twelve traditional and twenty two modified rice varieties available in the Northern Province and among them three traditional and six improved rice varieties are frequently consumed (Abeysekera *et al.* 2017). For this study seven traditional and seven improved rice varieties available at the Rice Development Institute, Paranthan, Northern Province of Sri Lanka and preferred by the people in the Northern Province were selected (Table 1). Three traditional and two improved rice varieties preferentially consumed in the Northern Province were selected for cooking by different traditional methods.

Pericarp colour of the raw rice samples

Except for *Suwandal*, all the other traditional rice varieties were with red pericarp while those of Bg250 and Bg366 were white among the improved rice varieties (Table 1). It is also important to note that the Northern Sri Lankans are more towards consuming red rice than the white rice. Except Bg250, all the other rice samples selected for cooking were red in colour.

The colours of the rice samples reported previously (*Murungakayan*, *Pachchapermal*, *Suwandal*, At362 and Bg366) observed and now (Table 1) are same (Rebeira, *et al*. 2014; Hettiarachchi, *et al*. 2016; Hafeel *et al*. 2020 and Sinthuja *et al*. 2021). The coloured rice varieties are considered to be having health benefits and are nutritious (Rathna Priya *et al*. 2019). Further the coloured rice varieties have antioxidant and free radical scavenging activities (Itagi and Singh, 2015).

Lengths of the raw rice

The mean length of the traditional rice varieties ranged between 5.0 ± 0.2 mm (*Suwandal*) and 5.9 ± 0.6 mm (*Pachchaperumal*) and differed significantly ($p<0.05$) (Table 1). The mean lengths of the improved rice varieties ranged from 4.9 ±0.9 mm (Ld356) to 7.2 ± 0.5 mm (Bg250) and differed significantly ($p<0.05$) (Table 1). However almost all the improved and traditional rice varieties had similar lengths, except At362 and Bg250 (Table 1).

The rice grains are classified based on their lengths as short (<5.5 mm), medium (5.5-6.60 mm), long (6.61-7.5 mm) and extra-long (>7.5 mm) (Juliano 1993) (Table 1). Among the traditional rice varieties, 5 had short and 2 had medium lengths (*Pachchaperumal* and *Periyavellai*). Both the medium length rice varieties were with red pericarp. Only one of the improved rice varieties was with long length (Bg250), and had white pericarp and the second rice with white pericarp was with medium length (Bg366). Except At362, all the other rice varieties with red pericarp were short in length (Table 1). *Suwandal* (3.69 mm, Rebeira, *et al*. 2014; 3.69mm, Hettiarachchi, *et al*. 2016; 4.02 mm Sinthuja *et al*. 2021 and 5.0 mm, Table 1) and *Pachchaperumal* (5.22 mm, Rebeira, *et al*. 2014; 5.22 mm, Hettiarachchi, *et al*. 2016 and 5.39 mm Sinthuja *et al*. 2021) were short but it has been observed that the *Pachchaperumal* local rice variety of the Northern Sri Lanka was of medium size (5.9 mm, Table 1). Bg366 is a medium sized rice (Rebeira, *et al*. 2014; Hettiarachchi, *et al*. 2016; Sinthuja *et al*. 2021 and Table 1)

The traditional rice varieties preferred by the Northern Sri Lankans are either medium or short in size while majority were red in colour. Similar preferences were also observed with the improved rice varieties except Bg250 (Table 1). Previous study has also supported this observation for the preference in other parts of Sri Lanka (Pathiraje, *et al*. 2010).

Amylose Contents of the Selected Raw and Cooked Rice Varieties

Among the traditional rice varieties, the highest and least amylose contents were present in *Periyavellai* and *Suwandal* respectively (Table 1). Amylose contents of the different Sri Lankan rice varieties showed variations (Abeysekera *et al*. 2016; Abeysekera *et al*. 2018) from the rice samples selected in this study. Amylose contents of the rice varieties also differ based on the climatic conditions, cultivar location and genetic variations (Wang *et al*. 2002; Singh *et al*. 2006; Patindol *et al*. 2010; Wang *et al*. 2010) and the rice samples collected for this study were from the Northern Province, which is a dry zone of the country.

Correlation between the lengths of traditional rice varieties and amylose contents was observed (R^2= 0.4468), while no such correlation was observed with the improved rice varieties (R^2= 0.0792). However, the longer grain varieties with the higher amylose contents have been reported (Williams *et al*. 1958; Gunaratne *et al*. 2019).

Variations in of 1 – 2% amylose contents are considered as waxy, 2 – 12% as low amylose, 20 - 25% as intermediate amylose and 25 - 33% as high amylose contents (Coffman *et al*. 1987). The rice varieties namely Kallundai, *Suwandal* and Tattu Wee had having intermediate amylose contents and the other traditional rice varieties had high amylose contents (Table 2). Among the improved rice varieties, except for Bg361 and Bw351 (high amylose contents) all the other rice varieties had intermediate amylose contents. Usually the rice varieties with low amylose contents are more palatable (Ramirez 1991). However the rice varieties *Moddakaruppan*, *Pachchaperumal*, *Periyavellai*, Bg250 and Bw351 were the preferred rice varieties in the Northern Province and among them *Moddakaruppan* and Bg250 are the most preferred rice varieties and their amylose contents were high and intermediate respectively (Table 1).

All the traditional and improved rice varieties showed a reduction in amylose contents by the traditional cooking methods undertaken in this study (Tables 1, 3 & 4). Among the different cooking methods, the highest amount of amylose contents was lost when rice samples were pre-soaked and cooked without excess water, followed by those cooked with excess water (Table 4). The reduction in amylose contents was least in the rice samples, which were roasted. The results indicated that the pre-soaking of the rice before cooking would have led to the activation of indigenous enzymes and led to the hydrolysis of the starch in the grains leading to greater loss of starch and amylose contents (Veluppillai 2009; Chandrasekar and Arasaratnam 2012). With all the different cooking methods, *Pachchaperumal* rice variety lost the highest amount of amylose and the loss was highest by pre-soaking and cooking without excess water, while Bg250 lost the least amylose and the loss was least when roasted (Table 4). The rice varieties with less amylose contents had shown easy digestibility (Pasakawee *et al*. 2018). This is evidenced with Bg250 when pre-soaked and cooked without excess water (Table 3).

Amylose Related to TS of the Selected Raw and Cooked Rice Varieties

As the amylose hydrolysis is relatively lower than the amylopectin (Hu *et al*. 2009), it was

Table 2: Resistant Starch (RS), RS related to Total Starch (TS), amylose related to TS and RS related to amylose contents of traditional and improved varieties raw rice.

Rice		Resistant Starch (%)	Total Starch (%)	RS to TS Content (%)	Amylose to TS content (%)	RS to Amylose (%)
Variety	Name					
Traditional	*Kallundaai*	1.6 ±0.1	90.42 ±0.1	1.7	25.8	6.6
	Moddakaruppan	1.1 ±0.1	76.51 ±0.1	1.4	35.4	4.0
	Murungagayan	1.0 ±0.1	89.21 ±0.1	1.1	29.0	3.8
	Pachchaperumal	2.0 ±0.2	89.89 ±0.2	2.2	31.1	7.2
	Periyavellai	1.2 ±0.1	90.01 ±0.3	1.3	31.5	4.2
	Suwandal	0.5 ±0.1	90.25 ±0.1	0.6	24.9	2.3
	Thattu Wee	3.3 ±0.4	89.52 ±0.2	3.7	25.7	14.3
Improved	*At362*	0.7 ±0.1	76.40 ±0.1	0.9	31.5	2.9
	Bg250	1.0 ±0.1	78.21 ±0.1	1.3	29.8	4.3
	Bg361	0.8 ±0.1	78.47 ±0.3	1.0	33.4	3.1
	Bg366	1.3 ±0.4	82.90 ±0.1	1.6	25.6	6.1
	Bw351	1.0 ±0.2	83.65 ±0.1	1.2	32.7	3.7
	Ld356	0.5 ±0.2	82.74 ±0.2	0.6	28.3	2.1
	Ld365	0.3 ±0.1	90.21 ±0.1	0.3	26.7	1.2

Mean of values ±SD. (standard deviation) (n=3). All results are given on dry weight basis.

Table 3: Amylose, amylose related to Total Starch (TS), Resistant Starch (RS), RS related to TS and RS related to amylose contents of traditional and improved varieties cooked by different methods.

Processing Method	Rice Variety	Amylose content (%)	Amylose to TS content (%)	Resistant (%)	RS Related to TS (%)	RS to Amylose (%)
Cooked without excess water	*Moddakaruppan*	19.4 ±0.3	31.1	0.2 ±0.1	0.4	1.0
	Pachchaperumal	18.7 ±0.8	29.1	0.6 ±0.1	1.0	3.2
	Periyavellai	20.2 ±1.0	35.8	0.6 ±0.1	1.1	3.0
	Bg250	18.2 ±1.0	33.1	0.4 ±0.1	0.7	2.2
	Bw351	21.1 ±0.5	32.4	0.8 ±0.0	1.3	3.8
Pre-soaked and Cooked without excess water	*Moddakaruppan*	16.3 ±0.5	26.9	0.9 ±0.1	1.5	5.5
	Pachchaperumal	15.2 ±0.4	24.6	1.8 ±0.1	2.9	11.8
	Periyavellai	17.4 ±0.7	33.4	1.1 ±0.1	2.1	6.3
	Bg250	16.0 ±0.7	31.4	0.7 ±0.0	1.4	4.4
	Bw351	15.8 ±0.4	26.2	0.8 ±0.1	1.3	5.1
Cooked with excess water	*Moddakaruppan*	17.3 ±1.0	29.6	0.1 ±0.1	0.2	0.6
	Pachchaperumal	16.6 ±0.4	27.5	0.4 ±01	0.7	2.4
	Periyavellai	18.3 ±0.7	34.7	0.5 ±0.0	1.0	2.7
	Bg250	16.5 ±0.5	32.4	0.3 ±0.1	0.6	1.8
	Bw351	18.4 ±0.7	30.7	0.6 ±0.1	1.0	3.3
Roasted	*Moddakaruppan*	24.0 ±0.5	32.3	0.1 ±0.1	0.1	0.4
	Pachchaperumal	22.5 ±0.6	34.0	0.5 ±0.1	0.8	2.2
	Periyavellai	24.4 ±0.7	41.7	0.6 ±0.1	1.0	2.5
	Bg250	21.1 ±0.8	36.8	0.4 ±0.1	0.7	1.9
	Bw351	24.4 ±0.4	31.2	0.7 ±0.1	0.9	2.9

Mean of values ±SD. (standard deviation) (n=3). All results are given on dry weight basis.

expected that the amylose related to TS contents (presented in percentage) of the raw and the cooked rice samples shall provide information on the effect of cooking.
There had been no correlations between grain length & amylose related to TS were observed in both traditional (R^2= 0.1029) and improved (R^2= 0.0181) raw rice varieties.

Amylose related to TS content among the traditional varieties of raw rice, *Moddakaruppan* was the highest and Tattu Wee was the least. *Pachchaperumal* and *Periyavellai* had almost same amount of amylose to TS contents. Among the raw improved rice samples, Bg361 contained the highest and Bg366 contained the least amylose contents. *Suwandal* and Bg366 had very close amylose to TS contents (Table 2).

The amylose to TS content of *Moddakaruppan* variety was the highest (Table 2) while it had substantial decreased by all the cooking methods selected ($p<0.05$) (Tables 3 and 5). The amylose to TS contents of *Periyavellai* and Bg250 were increased by all the cooking methods and the increase was more in *Periyavellai* than in Bg260 (Table 5, $p<0.05$). Roasting also had increased the amylose to TS contents of *Pachchaperumal*. The amylose to TS content changes varied between the cooking without excess water and pre-soaking and cooking without excess water depending on the rice varieties. The results indicated that soaking process had affected the amylose to TS contents leading to either increase or decrease, which were not related directly to the amylose contents of the raw rice. The variations could be due to the amounts and activities of the carbohydrates produced by the rice samples during soaking.

Resistant Starch Contents of the Selected Raw and Cooked Varieties of Rice

High RS content was observed in pigmented rice samples (Paskawee *et al*. 2011). This was only observed with the *Suwandal* but was not true with other rice varieties (Table 1). The RS contents of the traditional varieties of raw rice varied between 0.5 ±0.1% (*Suwandal*) and 3.3 ±0.4% (Tattu Wee) ($p<0.05$) (Table 2). Except the *Suwandal*, all the other traditional rice varieties had the RS contents above 1.0% (Table 2). *Moddakaruppan* and *Periyavellai* contained almost same amounts of RS. *Moddakaruppan* is the most preferred traditional rice variety for the taste and aroma but it did not contain substantial amount of RS than the other tested traditional rice varieties (Table 2). The RS contents of the improved varieties of raw rice varied between 0.3% ± 0.1 (Ld365) and 1.3% ± 0.4 (Bg366) (Table 2). Among the modified rice varieties, Bg250 is most preferred by the people in the Northern Province and it contained the 3rd highest amount of RS content among the improved rice varieties (Table 2). No correlations were observed between grain lengths & RS contents. The RS contents of the traditional rice varieties except *Suwandal*. Similar results have been reported for the Sri Lankan traditional and improved varieties (Abeysekera 2018). The variations in the RS contents of the selected rice samples from those reported by others may be due to the climatic condition in the Northern Province.

RS contents of cooked rice may decrease (Ahmad *et al*. 2015). All the rice varieties selected showed reduction in RS content following all the cooking methods undertaken in this study (Table 4). Raw uncooked rice has higher RS than its cooked rice (Yang *et al*. 2006). However the different rice varieties have shown different RS contents (Darandakumbura *et al*. 2013). Among the different cooking methods, highest amounts of the RS contents were reduced in the different rice samples, which were cooked with excess water followed with those roasted (Tables 3 and 4). Cooking methods have no effect on

Table 4: Amylose and RS contents of different varieties of raw rice and the changes in amylose and RS contents of the rice cooked by traditional methods.

Rice Variety	Raw (%)		Cooked without Excess Water (%)		Pre-soaked and Cooked without Excess Water (%)		Cooked with Excess Water (%)		Roasted (%)	
	Amylose	RS	Amylose	RS	Amylose	RS	Amylose	RS	Amylose	RS
Moddakaruppan	27.2	1.1	-28.7	-81.8	-40.1	-18.2	-36.4	-90.9	-11.8	-90.9
Pachchaperumaal	27.9	2.0	-33.0	-70.0	-45.5	-10.0	-40.5	-80.0	-19.4	-75.0
Periyavellai	28.6	1.2	-29.4	-50.0	-39.2	-8.3	-36.0	-58.3	-14.7	-50.0
Bg250	23.3	1.0	-21.9	-60.0	-31.3	-30.0	-29.2	-70.0	-9.4	-60.0
Bw351	27.4	1.0	-23.0	-20.0	-42.3	-20.0	-32.9	-40.0	-11.0	-30.0

(-) values indicate decrease and (+) values indicate increase in the parameter.

Table 5: Amylose related to TS, RS related TS and RS related to amylose contents of different varieties of raw rice and the changes in the above said parameters in rice cooked by traditional methods.

Rice Variety	Raw (%)			Cooked without Draining Water (%)			Pre-soaked and Cooked without Draining Water (%)			Cooked with Excess Water (%)			Roasted (%)		
	Amylose to TS	RS to TS	RS to Amylose	Amylose to TS	RS to TS	RS to Amylose	Amylose to TS	RS to TS	RS to Amylose	Amylose to TS	RS to TS	RS to Amylose	Amylose to TS	RS to TS	RS to Amylose
Moddakaruppan	35.4	1.4	4.0	-12.1	-71.4	-75.0	-24.0	+7.1	+37.5	-16.4	-85.7	-85.0	-8.8	-92.9	-90.0
Pachchaperumaal	31.1	2.2	7.2	-6.4	-13.6	-55.6	-20.9	+31.8	+63.9	-11.6	-68.2	-61.5	+9.3	63.6	-69.4
Periyavellai	31.5	1.3	4.2	+13.7	-15.4	-28.6	+6.0	+61.5	+50.0	+9.1	-23.1	-35.7	+31.1	-23.1	-40.5
Bg250	29.8	1.3	4.3	+11.1	-46.2	-48.8	+5.1	+7.7	+2.3	+8.7	-54.8	-58.1	+23.5	-46.2	-55.8
Bw351	32.7	1.2	3.7	-0.9	0.0	+2.7	-19.9	+8.3	+37.8	-6.1	-16.7	-10.8	-4.6	-25.0	-21.6

(-) values indicate decrease and (+) values indicate increase in the parameter.

the composition of rice (Darandakumbura *et al*. 2013) and no such observations were made in this study. High moisture treatment increased the RS content of rice flour (Noro *et al*. 2018). Pre-soaking and cooking without excess water lead to least loss of RS and retained highest amount of RS (Table 4). This might be due to the digestible starch hydrolysis, leaving the RS un-hydrolysed. Cooking with excess water lead to increased loss of RS. Highest loss of RS was observed in *Moddakaruppan* rice variety when it was cooked with or without excess water and roasting. It was found that the pre-soaking and cooking without excess water led to highest loss of RS in Bg250. Soaking led to increase in the RS contents of most of the food materials (Niba and Hoffman 2003). Pre-soaking might have led to the changes in the alignments of the starch in Bg250 and led to highest loss of RS (Trinh *et al*. 2013). The increase in RS contents from cooking without excess water than pre-soaking and cooking without excess water were 3.75, 3.0, 1.83, 1.75 and 1.0 folds in *Moddakaruppan*, *Pachchaperumal*, *Periyavellai*, Bg250 and Bw351 respectively. Previous studies have indicated that roasting of rice products increased the RS (Vatanasuchart *et al*. 2009) but not evidenced in this study.

Resistant Starch Related to TS Contents

The raw rice samples contained RS related to TS above 1.0% (Table 2). Among the traditional varieties of raw rice, the RS related to TS content was highest in Tattu Wee and the lowest in *Suwandal*. Among the improved varieties, the RS related to TS content of Bg366 was the highest and Ld365 was the least (Table 2). No correlations were observed between grain lengths and RS related to TS contents (traditional, R^2= 0.0475 and improved R^2= 0.2305).

RS related to TS contents of Bw351 was highest followed with *Pachchaperumal* while *Moddakaruppan* contained the least content, when cooked without excess water (Table 3). Highest reduction in RS related to the TS contents in *Moddakaruppan* followed with Bg250 (Table 5). The RS related to TS content of Bw351 was not changed after cooking without excess water (Table 5).

Pre-soaking and cooking without excess water led to highest RS related to the TS in *Pachchaperumal* contained and least in Bw351 (Tables 3). In all the rice samples the RS related to TS contents increased (Table 5) while highest and least increases were observed in *Pachchaperumal* and *Moddakaruppan* respectively (Table 5).

The RS related to TS contents of *Periyavellai* & Bw351 were the highest when cooked with excess water while least in *Moddakaruppan* (Table 3). The highest decrease in RS related to TS contents was in *Moddakaruppan* while least in Bw351 (Table 5).

Among the roasted rice samples, *Periyavellai* contained the highest and *Moddakaruppan* contained the least amount of RS related to TS contents. There had been highest reduction in RS related to TS contents in *Moddakaruppan* and least reduction in *Periyavellai* (Table 5).

The RS related to TS contents of all the rice samples decreased with the different cooking methods except that with the pre-soaking and cooking without excess water than the respective raw rice samples. The increase was highest in *Pachchaperumal* among the traditional rice varieties and in Bg250 among the improved rice varieties (Table 5). This indicated the loss of starch as well as the changes in the arrangements of starch polymers, causing reduction in the RS (Trinh *et al*. 2013).

Resistant Starch Related Amylose Contents

Among the raw rice samples *Thattu Wee* rice variety contained the highest RS related to amylose content while Ld365 contained the least (Table 2). *Periyavellai* and bg250 had almost same RS related to amylose contents (Table 2). The rice varieties which have more amylose contents were also expected to have more RS contents (Berry 1986; Siever and Pomeranz 1989; Hu *et al*. 2004; Sajilata *et al*. 2006; Birt *et al*. 2013; Chen *et al*. 2017). No correlations were observed between grain lengths and RS related to amylose contents (traditional R2= 0.0184; improved R2= 0.196).

When cooked without excess water, *Moddakaruppan* had the least while Bw351 had the highest RS related to amylose contents (Table 3). The decrease in RS related to amylose contents in the cooked rice was highest in *Moddakaruppan* while it was increased in Bw351 (Table 5).

Bg250 had the least and *Pachchaperumal* had the highest RS related to amylose contents after pre-soaking and cooking without excess water (Table 3). RS related to amylose contents were increased in all the rice samples after the cooking and the highest increase was observed in *Pachchaperumal* and least in Bg250 (Table 5).

After cooking with excess water, *Moddakaruppan* had the least and Bw351 had the highest RS related to amylose contents (Table 3). RS related to amylose content decrease was the highest in *Moddakaruppan* and least in Bw351 (Table 5).

Roasting the rice samples led to least RS related to amylose contents in *Moddakaruppan* while highest in Bw351 (Table 3). RS related to amylose content decrease was the highest in *Moddakaruppan* and least Bw351 (Table 5).

Under all the cooking conditions selected, amylose content was reduced than the respective raw rice samples (Tables 1, 2 and 3). Although the amylose content increases the RS formation, excess number of short chains of polysaccharides (DP < 10) inhibit the crystallization, and potentially create the amorphous structure leading to reduction in RS (Trinh *et al*., 2013). When the rice samples were cooked without excess ($R^2 = 0.3518$) and with excess ($R^2 = 0.351$) water showed correlation between amylose and RS contents while pre-soaking & cooking without excess water ($R^2 = 0.1393$) and roasting ($R^2 = 0.0398$) showed no correlation. It was also observed that the pre-soaking and cooking without excess water had led to an increase in amylose contents from 1.3 to 1.8 folds than in those cooked without excess water (Table 4).

When starch is heated in presence of water, the starch is gelatinized (Donovan, 1979; Jenkins *et al*. 1993; Jimenez *et al*. 2012). Gelatinization allows leaching of amylose (Donovan, 1979; Evans and Haisman 1982). This may be the reason for the loss of more starch from the rice when cooked with excess water and the water had been drained. In the rice which has been cooked without excess water had retained the gelatinized starch with the cooked rice (Table 4). The decrease in the amylose contents of the rice cooked without excess water was 1.27, 1.23, 1.23, 1.33 and 1.43 times higher in *Moddakaruppan*, *Periyavellai*, *Pachchaperumal*, Bg250 and Bw351 than those cooked with excess water. The decrease in the RS between the above said cooking methods were 1.11, 1.14, 1.17, 1.17 and 2.0 folds respectively. Thus, the loss of amylose related to RS were higher when the rice samples were cooked with excess water and the water was drained off.

the RS related to amylose contents of the selected rice varieties were increased when it was pre-soaked & cooked without excess water while it was decreased in all the rice varieties by other cooking methods except in Bw351, which was cooked without excess water.

CONCLUSION

It can be concluded that the RS content varied among the tested rice varieties and, the traditional rice varieties had higher RS content than improved rice varieties. Among all selected rice varieties traditional raw *Thattu Wee* rice variety contained highest percentage of RS content. Different processing methods have significantly reduced the total starch, amylose and RS contents. As the processed rice is consumed; consumption of pre-soaking and cooking without excess water of *Periyavellai* rice variety could be recommended to those who prefer to consume more RS. *Pachchaperumal* lost the highest amount of amylose among all the rice varieties and Bg250 lost least amount of amylose by all the processing methods.

AUTHOR CONTRIBUTION

PP did the laboratory work and prepared the manuscript, VA conceived the research idea, supervised and edited the manuscript.

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