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Effect of Parboiling on the Physicochemical and Phytochemicals Characteristics of Traditional Rice Cultivars

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ABSTRACT

Background: The indigenous rice varieties of India are cultivated and utilized by tribal peoples as well as people in the distant regions with traditional culture. The main aim of the research work was to explore the inherit beneficial characteristics of traditional rice cultivars over hybrid varieties.

Methods: The research work was aimed to investiagate the physicochemical and phytochemicals characteristics in traditional red rice cultivars (Mapillai Samba and Karungkuruvai) and traditional white rice cultivars (IR 20 and Improved White Ponni). The different treatments used in the study were raw rice (unpolished, polished) and parboiled rice (unpolished, polished). The interaction between physicochemical characteristics and phytochemicals were evaluated using Pearson correlation and Principal component analysis.

Result: The physicochemical characteristics were analyzed for all the rice cultivars. It was observed that parboiled-unpolished mapillai samba showed highest length, breadth, 1000 grain weight. The raw rice cultivars showed highest phytochemicals than parboiled rice. The total phenolic, total flavonoids and total anthocyanin contents were highest for the mapillai samba (raw rice-unpolished). Among different traditional rice cultivars, mapillai samba showed significantly higher antioxidant levels. The results of the study suggested that these traditional rice cultivars can be incorporated in value added products.

Key words: Multivariate analysis, Physicochemical characteristics, Phytochemicals, Traditional rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is a significant staple food for above half of the world's population and was more produced and consumed in the Asian countries. The cultivation and consumption of traditional grains is commonly distributed worldwide. At present, the traditional rice varieties are differentiated based on the colour intensity as red, black, purple and brown rice (Singh *et al.,* 2019).

Traditional red rice is an unpolished grain coated with germ, bran and endosperm. These grains are a store house of secondary metabolites and nutraceutical compounds like polyphenols, phenolic acids, tocopherols, tocotrienols, flavonoids, terpenoids, anthocyanins, proanthocyanidins and γ-oryzanol. The compounds are contributed to various health benefits as boosting of immunity, increasing memory power in children and fighting against cancer cells (Qayyum *et al.,* 2020). The traditional rice grains are generally cooked and consumed as a whole. Parboiled rice undergoes gelatinization and retrogradation and it change the structural features of rice starch, converting crystalline to amorphous form, producing very compact and translucent endosperm (Toutounji *et al,.* 2019).

Though considering the nutritional aspects of traditional rice varieties in the grain, the consumers are still restrained and are underutilized. Thus, keeping in view of above facts the present research work was undertaken with the objective to analyze physicochemical characteristics and phytochemicals content in traditional red and white rice varieties and their retention of the nutrients in raw and parboiled rice varieties in Tamil Nadu, India.

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MATERIALS AND METHODS

The experiments were conducted in the Department of Food Science and Nutrition, Community Science College and Research Institute, Madurai during month of Feburary, 2022. The traditional red rice cultivars *viz., mapillai samba* and *karungkuruvai* in the form of paddy were procured from Tamil Nadu Rice Research Station (TRRI), Aduthurai and from organic rice farmer, Srivilliputhur. The traditional white rice cultivars *viz.,* IR 20 and improved white ponni were obtained from Agricultural College and Research Institute, Madurai.

Analytical methods

Physicochemical and phytochemical analysis of selected rice cultivars

Ten rice kernels (undamaged and sound) of selected rice cultivars were analyzed for length (L) and breadth (B) using vernier caliper and were expressed in mm (Odenigbo *et al.,* 2014). Thousand grains from all samples were weighed by using an electronic weighing balance to determine thousand grains weight. Bulk density (BD) and porosity (P) of the rice samples were analyzed as per the procedure followed by Bhattacharya and Sowbhagya (1971), expressed as g/cc and percentage (%).

The cooking time (CT) for the selected rice samples were made as per the procedure followed by Simpson *et al.,* (1965). Solid loss (SL), kernel elongation ratio (KER), water absorption index (WAI) and water solubility index (WSI) were determined by Simpson *et al.,* (1965).The amylose and amylopectin were analysed by AOAC (2000).

Total phenols present in the extracts of selected traditional and white rice cultivars was done by Folin–Ciocalteau assay with a gallic acid standard (Singleton and Rossi, 1965). Total flavonoids present in rice sample extract of selected cultivars were determined by using aluminum chloride (Singh *et al.,* 2019). The existence of the total anthocyanins was estimated as per the procedure followed by Shen *et al.,* (2012) by pH differential method. The 2,2-diphenyl-1-picrylhydrazyl-radical scavenging activity (DPPH), ferric reducing antioxidant power (FRAP) and radical cation ABTS scavenging activity were analysed by using the method Lim *et al.,* (2007). The data obtained from the study were analysed by SPSS software of 2017 version of one-way analysis of variance (Snedecor and Cochran, 2004). Principal component analysis (PCA) was performed using XLSTAT software.

RESULTS AND DISCUSSION

Physicochemical characteristics of raw and parboiled rice cultivars

The physical properties *viz.,* L, B, 1000 grain weight, BD and P were assessed and presented in (Table 1). The length and breadth ranged from 5.02±0.06 to 5.92±0.13mm and 1.00±0.06 to 2.28±0.07 mm in selected rice varieties. The findings were comparable to the results obtained by Muthamilarasan *et al*., 2016 who analyzed the length, breadth and L/B ratios of 5.24 mm, 1.85 mm and 2.83 in navara, a traditional rice variety. The thousand grain weight of the rice cultivars ranged from 14.3 to 26.7 g. The bulk density ranged from 0.36±0.01 to 0.70±0.08 g/cc in selected rice cultivars. Sareepuang *et al*., (2018) reported that the traditional rice varieties have higher 1000 grain weight, bulk density and porosity when compared to the white rice varieties. The maximum and minimum porosity was observed in raw-unpolished IR 20 of 58.32±0.74% and 49.22±0.45% in raw-polished mapillai samba. Lee *et al.,* (2011) stated that the porosity of basmati and non basmati rice varieties ranged from 40 to 54% respectively.

The cooking characteristics *viz.,* CT, KER, SL, WAI, WSI, amylose and amylopectin are presented in (Table 2). The traditional rice cultivars required more time for cooking then white rice cultivars. Furthermore, this is consistent with

Table 1: Physical characteristics of selected rice varieties.

Treatments	Varieties	L (mm)	B (mm)	1000 grain weight (g)	BD (g/cc)	P (%)
Raw-unpolished	V_1	5.90±0.09	2.28±0.07	24.5±0.56	0.38±0.04	50.36±0.89
	V_2	5.79±0.11	2.07±0.08	21.4±0.55	0.42±0.01	52.94±0.93
	V_3	5.59±0.02	1.12±0.08	14.5±0.14	0.70±0.08	58.32±0.74
	V_4	5.75±0.12	1.58±0.05	18.4±0.06	0.61±0.01	55.82±0.65
Raw-polished	V_1	5.92±0.13	2.11±0.04	22.5±0.34	0.41±0.03	52.91±0.58
	V_2	5.81±0.11	2.00±0.08	20.3±0.29	0.43±0.03	53.15±0.86
	V_3	5.10±0.80	1.00±0.06	16.9±0.35	0.65±0.14	51.07±0.72
	V_4	5.49±0.11	1.51±0.07	18.1±0.11	0.63±0.09	56.19±0.64
Parboiled-unpolished	V_1	5.94±0.14	2.42±0.09	26.7±0.17	0.36±0.01	49.22±0.45
	V_2	5.87±0.07	2.16±0.05	22.9±0.76	0.40±0.05	51.92±0.51
	V_3	5.63±0.18	1.11±0.08	15.1±0.40	0.64±0.04	57.03±0.89
	V_4	5.79±0.10	1.65±0.06	18.9±0.61	0.55±0.02	54.20±0.06
Parboiled-polished	V_1	5.88±0.09	2.16±0.01	24.0±0.01	0.39±0.09	51.42±0.68
	V_2	5.72±0.13	1.90±0.02	20.3±0.61	0.45±0.07	53.73±0.69
	V_3	5.02±0.06	1.10±0.06	14.3±0.10	0.69±0.10	57.79±0.75
	V_4	5.41±0.03	1.27±0.05	18.5±0.25	0.59±0.04	54.78±0.88
SED		0.0961	0.1734	0.0981	0.0461	0.2652
CV (%)		2.49	2.15	2.06	2.13	2.52

V_1-Mapillai Samba, V_2-Karungkuruvai, V_3-IR 20, V_4-Improved White Ponni.

the study conducted by Pushpama and Reddy (2017). The KER ranged from 1.02±0.02 to 2.32±0.03% for the selected rice cultivars. The solid loss values varied from 3.91 to 4.97% in selected rice cultivars. The highest WAI of 2.44±0.01g/g was noted in raw-unpolished mapillai samba. Odenigbo *et al.,* 2014 reported that this difference in WAI is due to the disparity between the hydrogen and hydroxyl groups in forming a bond between the starch structures. Among the traditional rice cultivars, raw-unpolished mapillai samba showed highest WSI of 6.58±0.10g/g and with a lowest of 4.82±0.08g/g in parboiled-polished karungkuruvai. In case of white rice cultivars, the highest WSI was noted in raw-unpolished IR 20 of 5.59±0.16 g/g and least of 5.30±0.03g/g in parboiled-polished improved white ponni. The amylose content of traditional rice cultivars ranged from 23.4 to 28.9% and white rice cultivars ranged from 22.0 to 24.9% respectively. The amylopectin content ranged between 71.3 and 78.0% for the selected rice cultivars.

Phytochemical constituents in raw and parboiled rice cultivars

The phytochemical constituents were analyzed and depicted in (Table 3). The highest TPC was noticed in raw-unpolished mapillai samba of 43.13±0.78 mgGAE/100 g. Shen *et al.,* (2012) stated that among 492 rice accessions, TPC ranged

Table 2: Cooking characteristics of selected rice varieties.

Treatments	Varieties	CT (mins)	KER (%)	SL (%)	WAI (g/g)	WSI (g/g)	Amylose (%)	Amylopectin (%)
Raw -unpolished	V_1	45.05±0.05	1.12±0.02	3.84±0.08	2.44±0.01	6.58±0.10	23.4±0.66	76.6±0.65
	V_2	45.11±0.21	1.05±0.05	3.51±0.06	2.29±0.07	4.97±0.01	27.6±0.41	72.4±0.09
	V_3	30.10±0.22	1.96±0.03	4.85±0.01	2.19±0.01	5.59±0.16	22.0±0.65	78.0±0.25
	V_4	30.22±0.08	2.19±0.03	4.83±0.03	2.10±0.03	5.48±0.04	22.8±0.58	77.2±0.29
Raw -polished	V_1	45.29±0.79	1.09±0.02	3.81±0.10	2.32±0.02	6.42±0.14	25.2±0.74	74.8±0.62
	V_2	45.24±0.48	1.02±0.02	3.49±0.06	2.15±0.02	4.85±0.01	28.7±0.68	71.3±0.74
	V_3	30.42±0.66	1.89±0.02	4.83±0.09	2.07±0.05	5.44±0.05	23.2±0.20	76.8±0.85
	V_4	30.61±0.52	2.03±0.67	4.90±0.07	2.02±0.01	5.32±0.15	24.3±0.41	75.7±0.79
Parboiled -unpolished	V_1	20.54±0.16	1.15±0.02	3.91±0.03	2.39±0.06	6.55±0.08	23.9±0.26	76.1±0.93
	V_2	20.67±0.45	1.09±0.02	3.68±0.01	2.24±0.05	4.91±0.02	27.6±0.33	72.4±0.39
	V_3	10.52±0.04	2.08±0.03	4.97±0.04	2.12±0.01	5.56±0.06	22.0±0.01	78.0±0.36
	V_4	10.69±0.13	2.32±0.03	4.94±0.08	2.08±0.04	5.41±0.08	22.8±0.62	77.2±0.48
Parboiled -polished	V_1	20.71±0.21	1.10±0.02	3.89±0.01	2.28±0.02	6.41±0.07	25.9±0.03	74.1±0.59
	V_2	20.83±0.29	1.06±0.01	3.60±0.10	2.10±0.02	4.82±0.08	28.9±0.60	71.1±0.65
	V_3	10.67±0.16	2.01±0.06	4.89±0.05	2.05±0.03	5.40±0.01	23.7±0.72	76.3±0.52
	V_4	10.74±0.07	2.27±0.08	4.25±0.09	2.00±0.08	5.30±0.03	24.9±0.20	75.1±0.46
SED		0.5943	0.0265	0.1547	0.0396	0.4128	0.0597	0.2596
CV (%)		2.45	2.08	2.11	1.92	1.78	2.38	2.54

Table 3: Phytochemical constituents of selected rice varieties.

Treatments	Varieties	TPC (mg GAE/100g)	TFC (mg QE/100g)	TAC (mg/cy^{-3} glc/100g)	DPPH (% RSA)	FRAP (µmol/l)	ABTS (% inhibition)
Raw-unpolished	V_1	43.13±0.78	7.20±0.68	45.50±0.25	77.3±0.55	47.2±0.25	40.2±0.05
	V_2	41.11±0.69	7.11±0.55	52.54±0.29	75.1±0.87	41.6±0.14	32.4±0.77
	V_3	34.59±0.55	4.21±0.27	0.38±0.19	47.6±0.26	37.1±0.03	29.5±0.14
	V_4	31.43±0.29	4.16±0.32	0.16±0.08	41.1±0.56	30.8±0.36	24.6±0.32
Raw-polished	V_1	39.21±0.87	4.07±0.52	41.21±0.15	64.5±0.84	42.8±0.79	34.5±0.38
	V_2	38.43±0.82	4.01±0.01	48.20±0.35	55.4±0.74	32.7±0.31	27.4±0.04
	V_3	30.71±0.79	2.77±0.14	0.25±0.18	29.6±0.14	26.6±0.29	22.6±0.68
	V_4	28.44±0.65	1.03±0.11	0.14±0.09	19.4±0.11	24.1±0.23	20.3±0.29
Parboiled-unpolished	V_1	41.93±0.49	6.11±0.35	49.74±0.10	68.1±0.58	44.5±0.21	37.5±0.10
	V_2	41.27±0.52	6.29±0.73	54.22±0.03	57.9±0.98	34.2±0.79	28.6±0.19
	V_3	34.54±0.39	3.47±0.81	0.61±0.09	31.6±0.28	29.4±0.60	21.5±0.48
	V_4	33.09±0.65	3.13±0.42	0.54±0.28	26.4±0.75	21.3±0.19	18.6±0.10
Parboiled-polished	V_1	37.48±0.80	3.73±0.11	43.54±0.08	51.3±0.28	30.4±0.93	30.2±0.25
	V_2	36.41±0.76	3.44±0.04	47.87±0.14	42.8±0.08	21.5±0.58	21.3±0.54
	V_3	26.87±0.19	1.98±0.09	0.28±0.22	22.5±0.29	20.2±0.59	17.4±0.56
	V_4	25.21±0.21	0.94±0.03	0.16±0.06	11.9±0.30	18.5±0.37	15.2±0.16
SED		0.1467	0.0982	0.2168	0.0519	0.1501	0.1138
CV (%)		2.07	2.24	2.03	1.29	1.14	2.15

Table 4: Correlation matrix (Pearson correlation coefficient) among different physical parameters, cooking characteristics, phytochemicals and antioxidant activities of selected rice cultivars ($p \leq 0.05$).

	L	B	1000 g wt	BD	P	CT	KER	SL	WAI	WSI	Amys	Ampc	TPC	TFC	TAC	DPPH	FRAP	ABTS
L	1																	
B	0.803	1																
1000 g wt	0.704	0.931	1															
BD	-0.659	-0.913	-0.902	1														
P	-0.659	-0.720	-0.731	0.807	1													
CT	0.445	0.373	0.332	-0.549	-0.400	1												
KER	-0.560	-0.847	-0.763	0.906	0.657	-0.550	1											
SL	-0.517	-0.836	-0.761	0.918	0.659	-0.449	0.938	1										
WAI	0.787	0.820	0.795	-0.717	-0.613	0.502	-0.737	-0.582	1									
WSI	0.427	0.361	0.509	-0.294	-0.400	0.128	-0.177	-0.010	0.652	1								
Amys	0.142	0.521	0.400	-0.667	-0.367	0.292	-0.716	-0.822	0.113	-0.453	1							
Ampc	-0.142	-0.521	-0.400	0.667	0.367	-0.292	0.716	0.822	-0.113	0.453	-1.000	1						
TPC	0.832	0.880	0.769	-0.773	-0.647	0.517	-0.841	-0.754	0.896	0.320	0.374	-0.374	1					
TFC	0.734	0.747	0.634	-0.575	-0.417	0.489	-0.668	-0.550	0.859	0.252	0.210	-0.210	0.907	1				
TAC	0.627	0.921	0.829	-0.926	-0.665	0.463	-0.973	-0.952	0.740	0.137	0.740	-0.740	0.864	0.717	1			
DPPH	0.779	0.831	0.731	-0.758	-0.577	0.672	-0.831	-0.692	0.931	0.375	0.334	-0.334	0.945	0.926	0.831	1		
FRAP	0.768	0.653	0.630	-0.590	-0.532	0.678	-0.620	-0.449	0.921	0.548	0.012	-0.012	0.831	0.847	0.600	0.917	1	
ABTS	0.766	0.753	0.742	-0.697	-0.563	0.654	-0.726	-0.561	0.969	0.612	0.103	-0.103	0.875	0.844	0.701	0.944	0.968	1

Total variance explained by principal component analysis

PC	Eigen value	Variability (%)	Cumulative (%)
1	11.88	66.03	66.03
2	3.24	18.05	84.08
3	1.15	6.42	90.50
4	0.72	4.02	94.52

L: Length, B: Breadth, 1000 g wt: Thousand grain weight, BD: Bulk Density, P: Porosity, CT: Cooking time, KER: Kernel elongation ratio, SL: Solid loss, WAI: Water absorption index, WSI: Water solubility index, Amys: Amylose, Ampc: Amylopectin, TPC: Total phenolic content, TFC: Total flavonoids content, TAC: Total anthocyanin content, DPPH: 2,2-diphenyl-1-picrylhydrazyl, FRAP: Ferric reducing antioxidant power, ABTS: 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt.

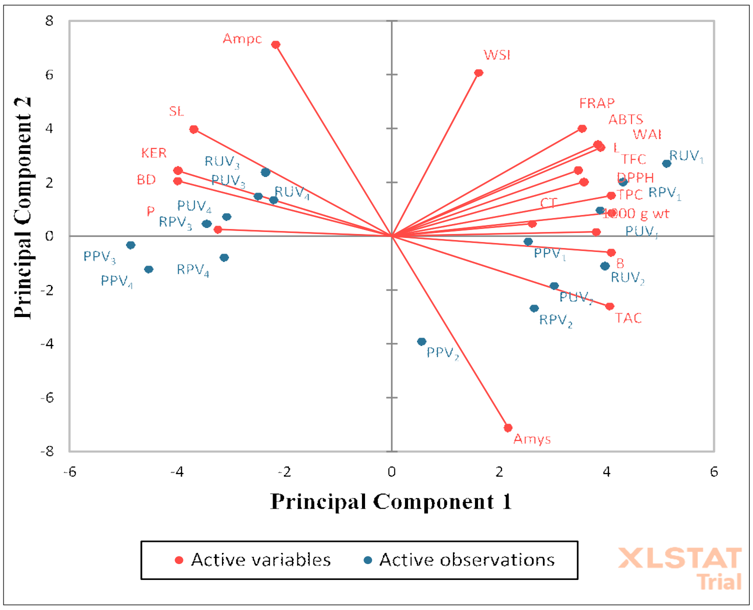

Fig 1: Projections of the variables as of PCA on the factor plane for four rice cultivars with different treatments.

from 108.1 to 1244.9mgGAE/100 g. The maximum and minimum TFC was observed in raw-unpolished mapillai samba of 7.20±0.68 mgQE/100 g and 0.94±0.03 mgQE/100 g in parboiled-polished improved white ponni. The highest TAC was noted in parboiled-unpolished karungkuruvai of 54.22±0.03 mgcy-3glc/100 g. Ghasemzadeh *et al.,* (2015) analyzed and reported the mean flavonoid contents of red, black and white rice of 137.3, 125.7 and 194.2 mgRE/100 g.

The maximum DPPH activity was observed in raw-unpolished mapillai samba of 77.3±0.55% and minimum in parboiled-polished improved white ponni 11.9±0.30%. The FRAP activity ranged between 18.5±0.37 and 47.2±0.25%. The highest value of radical cation ABTS scavenging activity was noted in raw-unpolished mapillai samba of 40.2±0.05% and lowest in parboiled-polished improved white ponni of 15.2±0.16%. There was a significant difference in all the treatments of selected rice cultivars. Lee *et al.,* (2011) investigated 582 rice cultivars *viz.,* pigmented and non pigmented rice cultivars and stated that pigmented rice cultivars (red and blackish purple rice) had highest antioxidant activity then non pigmented rice cultivars.

Multivariate analysis

The principal components analysis (PCA) was used in the experiment to minimize the reduction of research data while keeping the maximum number of variables in the study. (Table 4) shows the 'Eigen' value, as well as the variability percent and cumulative per cent. The factor loading computed for the first four components (PCs) are presented in (Table 5). In the analysis of selected rice cultivars, the first four principal components (PC1, PC2, PC3 and PC4) accounted for 94.52% of the variance, while PC1 for 66.03%, PC2 for 18.05%, PC3 for 6.42% and PC4 for 4.02% respectively. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.689.

Table 5: Principal component analysis and loading of the first four principal components.

	Principal components			
Factor loading	1	2	3	4
L	0.802	0.295	-0.054	-0.111
B	0.941	-0.073	-0.221	-0.172
1000 g wt	0.878	0.020	-0.382	-0.041
BD	-0.922	0.248	0.211	-0.180
P	-0.746	0.030	0.394	-0.303
CT	0.604	0.056	0.524	0.576
KER	-0.919	0.292	-0.031	-0.036
SL	-0.851	0.479	0.069	-0.008
WAI	0.899	0.397	-0.010	-0.075
WSI	0.373	0.733	-0.456	0.193
Amys	0.500	-0.859	0.056	0.018
Ampc	-0.500	0.859	-0.056	-0.018
TPC	0.946	0.106	0.113	-0.200
TFC	0.825	0.243	0.324	-0.343
TAC	0.936	-0.316	-0.029	-0.104
DPPH	0.943	0.182	0.251	-0.059
FRAP	0.818	0.484	0.253	0.072
ABTS	0.886	0.411	0.138	0.057

The data from the loading matrix presented in (Table 5) revealed that PC1=66.03% of the variability was positively correlated with variables such as L, B, 1000 g wt, CT, WAI, TPC, TFC, TAC, DPPH, FRAP and ABTS, whereas WSI was negatively correlated with BD (Fig 1), which determines physicochemical characteristics of traditional and white rice cultivars. The second component, had positive correlation with amylopectin (PC2=18.05%). The third component (PC3=6.42%) had positive correlation with CT and a negative correlation with the WSI. The fourth component

(PC4=4.02%) had positive correlation with CT but a negative correlation with TFC.

On the left side of PC2, RUV_3, PUV_3, RPV_3, RUV_4 and PUV_4 treatments were linked to SL, KER, BD, P and amylopectin as shown in (Fig 1). RUV_1, RPV_1, PUV_1, PPV_1, RUV_2, PUV_2, RPV_2, PPV_2, RUV_2, PUV_2, RPV_2, PPV_2 are located on the right side of PC1 related to L, B, 1000 grain weight, amylose, CT, WSI, WAI, TPC, TFC, TAC, DPPH, FRAP and ABTS.

CONCLUSION

In the midst of different treatments, it was perceived that parboiled-unpolished mapillai samba variety showed highest length, breadth and thousand grains weight followed by other rice cultivars. The highest value of bulk density and porosity were noticed in raw-unpolished IR 20 variety. The highest KER and solid loss were noted in parboiled-unpolished improved white ponni and IR 20 rice cultivars. The WAI and WSI were higher in raw-unpolished mapillai samba variety. The amylose content was higher for parboiled-polished karungkuruvai and improved white ponni rice cultivars .

The phytochemical contents and antioxidant activities were higher for the traditional red rice cultivars when compared to white rice cultivars. The correlation between physicochemical characteristics and phytochemicals had common or closely related pathways which were revealed by factor loading in PC1 and PC2, as well as the results of Pearson correlation analysis, demonstrating the reliability of the current experimental system. Hence, the study concludes that the variation in physicochemical characteristics maybe due to the varietal differences in selection of rice cultivars. The indigenous rice varieties are known to have potential in developing nutraceutical and functional foods. Utilization of these indigenous rice varieties in the form of value-added products by using traditional fermentation technique is likely to improve the gut microbiota and short chain fatty acids which in turn improve the consumption significantly at higher rates. As a result, there is a need to promote these rice varieties through improved production and processing, so that the individual can consume phytochemical-rich foods and improve their nutrition.

Conflict of interest: None.

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