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Relationships between Grain Physicochemical Characteristics and Flour Particle Size Distribution for Taiwan Rice Cultivars

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ABSTRACT

Fourteen cultivars of rice, 5 indica, 6 japonica and 3 waxy types were used to investigate the relationship between grain physicochemical characteristics and particle size distributions of rice flour. The data showed that particle size index (PSI) negatively correlated with the resistance time (RT) and milling temperature of Stenvert hardness test, damaged starch of rice flour, and percentage retained on 60 mesh (> 60 mesh %) ($p < 0.05$), but positively correlated with percentage that passed through 60 mesh and retained on 100 mesh (60-100 mesh %) ($p < 0.05$). From principal component analysis (PCA), the first and the second principal components, describing 56.14 and 21.44% of the variance of rice samples, respectively. The first principal component highly correlated with variables including RT, > 60 mesh %, milling temperature of Stenvert hardness test and damaged starch of rice flour, but negatively correlated with hardness index of Brabender micro-hardness test (BMHT), 60-100 mesh % and PSI. The second principal component positively correlated with ash and fat contents, but negatively correlated with shape and thousand-kernel weight (TKW) of rice grains. The effect of protein content was intermediate between the first and second principal component. Based on the results of PCA, the rice grain physical characteristics (i.e., RT and BMHT) are major factors, followed by chemical compositions, affecting the rice flour particle size distributions.

Key words: rice grain, physicochemical characteristics, particle size distribution, principal component analysis

INTRODUCTION

Grain hardness is one of the most important criteria of rice quality. Juliano(1) reported that rice grain hardness was significantly related to protein content, but Goodman and Rao(2) could not confirm this result. Grain hardness was not correlated with amylose content or gelatinization temperature(3,4) while Lu *et al*.(5) shown a positive relationship as the differences in amylose content broadened. Chen et al.(6) reported that softer indica varieties had a more chalky area than harder varieties, but did not find the same within japonica and waxy varieties. The chalky areas of rice contribute to grain breakage during milling because it is softer than the translucent portions(7).

When rice is to be processed into various traditional products, snacks, breakfast cereals and other cooked or extruded products, it is first milled and ground into flour and sieved into different sizes(8,9). The particle size distribution of rice flour is known to play an important role in its functional properties and the quality of end products(10,11). In addition to inherent starch properties, storage history and milling processes, the hardness of rice grain may also be a significant factor in the particle size distribution of rice flour, but few systematic investigations in this area have been reported.

In a previous study(6), 14 Taiwan rice cultivars were characterized for their grain hardness and endosperm microstructure. The aim of this work was to examine the relationship between the physicochemical properties of rice grains and particle size distributions of rice flours from these 14 Taiwan rice cultivars.

MATERIALS AND METHODS

I. *Materials*

Fourteen milled rice of 1996's first crop from the Taichung District Agricultural Improvement Station (Changhua, Taiwan) were used as samples(6). There were 4 high amylose indica cultivars (Kaohsiung Sen 7, KSS7; Taichung Native 1, TCN1; Taichung Sen 17, TCS17 and Tainung Sen 19, TNuS19), 1 low amylose indica cultivar (Taichung Sen 10, TCS10), 6 japonica cultivars (Kaohsiung 142, KS142; Taichung 189, TC189; Taigeng 5, TG5; Taigeng 8, TG8; Taigeng 9, TG9 and Tainan 9, TN9), 2 japonica waxy cultivars (Taichung Waxy 70, TCW70 and Taigeng Waxy 1, TGW1) and 1 indica waxy cultivar (Taichung Sen Waxy 1, TCSW1). All rice samples were stored at 4°C until use.

II. *Analytical Methods*

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(I) *Proximate analysis*

For both chemical analysis and damaged starch measurement, the polished rice kernels were ground into flour using an Udy cyclone mill equipped with a 1–mm screen (Udy Corp., Fort Collins, CO). The moisture, crude protein, crude lipid, and ash contents of the rice flour were determined by AACC methods 44-15A, 46-11A, 30-10 and 08-01, respectively(12). A conversion factor of 5.95 was applied for the calculation of crude protein content. Damaged starch was measured with a MegaZyme (Australia) test kit(13). All measurements were in triplicate.

(II) *Thousand kernel weight and kernel shape*

The thousand kernel weight (TKW; dry basis) was measured by the method of Adair *et al*.(14). Kernel length and width were calculated from the mean of 30 kernels measured with digital calipers (Mitutoyo Co., Japan).

(III) *Grain hardness and milling temperature*

Grain hardness and milling temperature were described in a previous work(6). The grain hardness of the polished rice was determined by the Stenvert hardness test and the Brabender micro-hardness test (BMHT). The Stenvert hardness test was conducted according to the methods of Stenvert and Kingswood(15). BMHT was carried out by the method described by Miller *et al*.(16). Milling temperature was measured when the ground flour sample was collected for the Stenvert hardness test.

(IV) *Particle size distribution*

Polished rice was ground into flour by a Culatti micro hammer mill (Culatti, type MDCI, Zurich, Switzerland) with a 1-mm screen. The particle size distribution of the flour was determined by sieving a 50 g sample with a Ro-Tap testing sieve shaker and a succession of 60, 100, 150, 200 and 250-mesh sieves. The amount from each sieve was recorded as a percentage of total recovery. The particle size index (PSI) was calculated by the method of Khan *et al*.(17).

(V) *Statistical analysis*

Data were analyzed by Statistical Analysis System (SAS)(18). Analysis of variance (ANOVA), correlation analysis, Duncan's multiple range test and principal component analysis (PCA) were performed when appropriate(19, 20).

RESULTS AND DISCUSSION

I. *Physicochemical Characteristics of Milled Rice*

Moisture content of the 14 rice cultivars ranged from 11.77 to 12.88%. The crude protein contents of indica rice ranged from 6.16 to 7.61%, japonica rice ranged from 6.30 to 7.47%, and waxy rice from 7.02 to 7.77%. TCSW1 (waxy) and TCN1 (indica) had the highest crude protein contents (Table 1). The crude lipid contents of indica rice ranged from 0.37 to 0.77%, japonica rice ranged from 0.62 to 1.14%, and waxy rice from 0.72 to 1.39%. Ash contents were in the range of 0.38 to 0.61%. TCS17 had the highest TKW (30.3g; dry basis), with other cultivars ranging between 21.0 and 24.5g. The kernel length-width ratio of indica cultivars ranged from 2.01 to 2.99, japonica rice ranged from 1.59 to 1.76, and waxy rice from 1.45 to 2.54. Damaged starch contents of the cyclone-mill milled rice

Table 1. Chemical compositions and physical properties of 14 polished rice grains[a,b]

Rice cultivars	Moisture (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Damaged starch (%)	1000 Kernel weight (g)	Length (mm)	Width (mm)	Length-width ratio
Indica									
KSS7	11.80 ± 0.05f[c]	6.40 ± 0.04f	0.38 ± 0.02f	0.38 ± 0.00i	4.86 ± 0.23g	24.48 ± 0.33b	5.85 ± 0.20d	2.64 ± 0.10e	2.22 ± 0.13d
TCN1	11.77 ± 0.08f	7.61 ± 0.04ab	0.71 ± 0.03de	0.56 ± 0.03c	5.98 ± 0.19f	21.86 ± 0.16e	5.35 ± 0.21e	2.67 ± 0.11e	2.01 ± 0.10e
TCS17	11.97 ± 0.02de	6.47 ± 0.02ef	0.37 ± 0.02f	0.53 ± 0.01d	4.83 ± 0.16g	30.28 ± 0.10a	6.21 ± 0.23c	2.87 ± 0.09cd	2.16 ± 0.11d
TNuS19	12.55 ± 0.09b	6.16 ± 0.04g	0.77 ± 0.01d	0.59 ± 0.01b	7.80 ± 0.36de	22.57 ± 0.35d	6.64 ± 0.21a	2.22 ± 0.08g	2.99 ± 0.15a
TCS10	12.74 ± 0.05a	7.16 ± 0.02c	0.45 ± 0.03f	0.51 ± 0.01e	8.78 ± 0.34abc	22.68 ± 0.41d	6.42 ± 0.19b	2.40 ± 0.14f	2.69 ± 0.15b
Japonica									
KS142	12.42 ± 0.08b	7.10 ± 0.37c	0.95 ± 0.14c	0.59 ± 0.00b	8.89 ± 0.78ab	22.65 ± 0.29d	4.76 ± 0.19g	2.86 ± 0.09d	1.66 ± 0.08gh
TC189	12.22 ± 0.17c	7.47 ± 0.05b	0.64 ± 0.04e	0.47 ± 0.02g	8.89 ± 0.25ab	20.99 ± 0.60f	4.93 ± 0.18f	2.88 ± 0.11cd	1.71 ± 0.10fg
TG5	12.78 ± 0.10a	6.64 ± 0.02de	0.69 ± 0.04de	0.44 ± 0.01h	9.19 ± 0.71a	22.47 ± 0.76d	4.69 ± 0.23g	2.83 ± 0.12d	1.66 ± 0.09ghi
TG8	11.86 ± 0.06ef	6.68 ± 0.04d	0.70 ± 0.03de	0.49 ± 0.01f	7.79 ± 0.39de	23.36 ± 0.30c	4.75 ± 0.13g	2.99 ± 0.08ab	1.59 ± 0.05i
TG9	12.88 ± 0.06a	6.67 ± 0.08d	1.14 ± 0.09b	0.61 ± 0.01a	8.66 ± 0.79abc	22.76 ± 0.32d	5.02 ± 0.19f	2.86 ± 0.12d	1.76 ± 0.09f
TN9	12.10 ± 0.04cd	6.30 ± 0.01fg	0.62 ± 0.01e	0.54 ± 0.01d	7.51 ± 0.28e	21.60 ± 0.25e	4.64 ± 0.13g	2.9 ± 0.10cd	1.60 ± 0.07hi
Waxy									
TCW70	12.51 ± 0.16b	7.02 ± 0.04c	0.72 ± 0.02de	0.38 ± 0.02i	8.07 ± 0.20cde	21.12 ± 0.29f	4.40 ± 0.23h	3.03 ± 0.12a	1.45 ± 0.07j
TGW1	12.02 ± 0.06de	7.08 ± 0.08c	1.39 ± 0.06a	0.61 ± 0.02a	7.69 ± 0.44de	22.32 ± 0.28d	4.44 ± 0.10h	2.94 ± 0.11bc	1.51 ± 0.06j
TCSW1	12.50 ± 0.19b	7.77 ± 0.02a	0.91 ± 0.04c	0.52 ± 0.00de	8.40 ± 0.58bcd	23.64 ± 0.14c	6.24 ± 0.20c	2.46 ± 0.07f	2.54 ± 0.12c

[a] Data are mean ± standard deviations, $n = 3$.

[b] Dry basis.

[c] Mean values in a column with different letters are significantly different ($p < 0.05$).

flour ranged from 4.83 (TCS17) to 9.19% (TG5), and significant differences were observed among the 14 cultivars (Table 1). Chen(21) have shown that differences in damaged starch can be attributed to differences in rice endosperm structure and milling methods.

Grain hardness indexes (RT and BMHT) and milling temperatures of Stenvert hardness test determined previously(6) and particle size distribution measured in the present study are listed in Table 2. The resistance times (RT) of the Stenvert hardness test ranged from 37.17 (KSS7) to 159.17 sec (KS142), and while the Brabender micro-hardness test (BMHT) results ranged from 10.85 (TG5) to 35.70 sec (TN9). The coefficients of variation (CV) calculated from RT and BMHT among 14 rice cultivars were 38.4 and 35.2%, respectively(6). Pomeranz and Webb(7) stated that higher RT and lower BMHT corresponded to harder rice kernels.

The statistical analysis showed that RT and BMHT were highly correlated with damaged starch ($p < 0.05$), but not with crude protein, ash or fat contents (Table 3). It was suggested that damaged starch is sensitive to differences in rice grain hardness and that it may serve as a good indicator for screening grain hardness. Similar results have also been found for wheat and maize(22,23).

II. *Particle Size Distribution*

When particle size distribution of the hammer-milled rice flours were determined by sieving, for most cultivars, more than 80% of the flour were retained on the 60 and 100 mesh sieves (Table 2). In addition, when the rice grains with RT > 100 sec, almost more than 80% of the rice flours were retained on the 60 mesh sieve. TG5 and KS142 had the lowest BMHT and showed 86% and 6-7% of the rice flours were retained on the 60 and 100 mesh sieves, respectively. On the contrary, rice grains (i.e., KSS7 and TCS17) with lower RT gave lower values on the 60 mesh sieve (63-64%) and higher on the 100 mesh sieve (17-19%). Among the various sieves, data from the percentage of those that passed through the 60 mesh and retained on the 100 mesh (60-100 mesh %) had the highest CV (42.19%). It is suggested that variability of 60-100 mesh % was high and it may be useful in separating the rice cultivars and could be considerable for the development of rice flours. Statistical analysis showed that data for the percentage retained on 60 mesh (> 60 mesh %) and 60-100 mesh % was highly correlated to RT and damaged starch of rice flour (Table 3).

Particle size indexes (PSI) ranged from 7.01 (TG5) to 8.74 (KSS7) (Table 2) and was in agreement with Pomeranz and Webb(7), who found that harder grains correlated with lower PSI values. In this study, the PSI highly correlated with RT ($r = -0.85$, $p < 0.01$), and a significant correlation between PSI and > 60 mesh % and 60-100 mesh % was also found. However, there was no significant correlation between PSI and BMHT (Table 3). In a previous study(6), we reported that the lowest milling temperature of Stenvert hardness test came from the KSS7 and TCS17, and the highest from the KS142, TC189 and TG5, and ranging from 36.3 (KSS7) to 46.6°C (KS142) (Table 2). Statistical analysis showed that the milling temperature of Stenvert hardness test positively correlated with RT, > 60 mesh % and damaged starch of rice flour ($p < 0.05$), and negatively correlated with BMHT, 60-100 mesh % and PSI ($p < 0.05$) (Table 2 and 3). These results were in agreement with

Table 2. Grain hardness index[a], milling temperature[a] and particle size distribution[b] of 14 Taiwan rice cultivars

Rice cultivars	Hardness index		Particle size distribution (%)						PSI[c]	Milling temperature (°C)
	RT[d] (sec)	BMHT[e] (sec)	> 60 mesh	60-100 mesh	100-150 mesh	150-200 mesh	200-250 mesh	< 250 mesh		
Indica										
KSS7	37.17	31.04	63.89	16.79	8.89	6.26	2.57	1.60	8.74	36.32
TCN1	67.50	23.96	71.92	16.62	7.85	2.56	0.41	0.64	7.77	37.93
TCS17	40.50	24.40	63.36	19.18	8.53	5.42	2.21	1.30	8.64	36.75
TNuS19	142.17	17.49	81.26	6.98	3.14	3.21	2.37	3.04	7.28	43.23
TCS10	152.83	17.10	82.36	7.70	3.73	3.29	1.78	1.14	7.37	43.42
Japonica										
KS142	159.17	12.57	86.24	6.24	5.28	1.68	0.36	0.20	7.02	46.63
TC189	158.33	14.70	84.13	7.24	4.89	2.75	0.77	0.22	7.25	45.72
TG5	141.67	10.85	86.06	6.80	4.11	2.01	0.59	0.43	7.01	44.28
TG8	103.50	21.85	80.27	12.18	5.15	1.73	0.44	0.23	7.26	38.55
TG9	132.33	13.75	81.13	7.37	7.21	3.07	0.71	0.51	7.48	42.05
TN9	68.33	35.70	74.71	16.84	6.35	1.91	0.06	0.13	7.52	37.48
Waxy										
TCW70	111.67	31.42	80.14	10.40	7.07	2.02	0.25	0.12	7.38	43.70
TGW1	101.50	25.33	79.48	12.41	5.63	1.96	0.31	0.21	7.32	40.77
TCSW1	136.00	25.29	82.51	7.13	5.60	3.12	0.97	0.67	7.37	41.72

[a] Data from previous work(6).

[b] Values are the average of two determinations.

[c] PSI: particle size index value is higher for finer flours(15).

[d] RT: resistance time of Stenvert hardness test, in which higher values correspond to harder kernels(28).

[e] BMHT: grinding time of Brabender micro-hardness test, in which lower values correspond to harder kernels(29).

Table 3. Correlation coefficients among grain hardness indexes (RT and BMHT)[a], milling temperature[a], and physicochemical characteristics of rice cultivars

	RT	BMHT	> 60 mesh	60-100 mesh	Milling temperature	Moisture	Crude protein	Ash	Crude fat	Damaged starch	TKW	Length-width ratio
BMHT	-0.73**[b]											
> 60 mesh	0.95**	-0.62*										
60-100 mesh	-0.97**	0.72**	-0.91**									
Milling temperature	0.93**	-0.69**	0.87**	-0.91**								
Moisture	0.75**	-0.56*	0.68**	-0.80**								
Crude protein	0.34	-0.14	0.34	-0.28	0.33	0.01						
Ash	-0.52	0.46	-0.38	0.63*	-0.48	-0.68**	0.01					
Crude fat	-0.27	0.51	0.01	0.29	-0.25	-0.40	0.07	0.60*				
Damaged starch	0.93**	-0.58*	0.98**	-0.89**	0.84**	0.75**	0.29	-0.35	0.01			
TKW	-0.52	0.09	-0.65*	0.49	-0.50	-0.27	-0.30	-0.11	-0.34	-0.64*		
Length-width ratio	0.09	-0.10	-0.14	-0.13	-0.04	0.19	-0.05	-0.55*	-0.70**	-0.17	0.27	
PSI	-0.85**	0.50	-0.96**	0.78**	-0.76**	-0.55*	-0.30	0.24	-0.17	-0.93**	0.70**	0.22

[a] Data from previous work(6).

[b] RT: resistance time of Stenvert hardness test; BMHT: grinding time of Brabender micro-hardness test; TKW: thousand kernel weight; PSI: particle size index.

[c] One asterisk indicates significance at the 0.05 level; two asterisks indicate significance at the 0.01 level.

Table 4. Correlation coefficients between principal component axes and grain hardness index (RT and BMHT)[a, b], milling temperature[a] and physicochemical characteristics of rice cultivars

	First component (56.14%)[c]	Second component (21.44%)
RT	0.99	-0.03
BMHT	-0.72	0.31
> 60 mesh %	0.96	0.23
60-100 mesh %	-0.98	0.11
Milling temperature	0.93	0.00
Moisture	0.80	-0.30
Crude protein	0.32	0.26
Ash	-0.55	0.68
Crude fat	-0.23	0.89
Damaged starch	0.95	0.24
TKWb	-0.56	-0.60
Length-width ratio	0.03	-0.80
PSI[b]	-0.87	-0.38

[a] Data from previous work(6).

[b] RT: resistance time of Stenvert hardness test; BMHT: grinding time of Brabender micro-hardness test; TKW: thousand kernel weight; PSI: particle size index.

[c] Percentage of variation explained by the component.

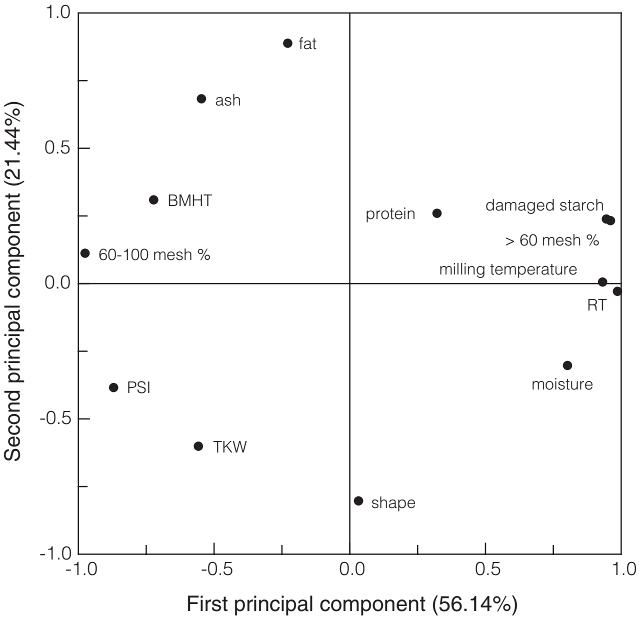

Figure 1. Loading plot with first and second components of the principal component analysis of the 13 variables of the physicochemical attributes of rice grains. RT is resistance time, BMHT is Brabender micro-hardness grinding time, TKW is thousand kernel weight, PSI is particle size index, 60 mesh (%) and 100 mesh (%) are the particle size indices measured with over 60 and 100 mesh sieves, respectively.

Wu(24), who reported that the hardness of corn grain highly correlated with mean particle size and sieved yields of the grits. Faridi *et al*.(25) stated a high correlation between wheat kernel hardness as measured by PSI (r = -0.93) or by SEM (r = 0.92) and finished product texture hardness.

IV. *Principal Component Analysis*

A principal component analysis (PCA) was performed with 13 normalized variables (listed in Table 4) of the physicochemical attributes of the 14 rice cultivars. With this statistical method, a large number of variables are reduced to some smaller number of orthogonal variables called principal components (PC), which accounted for the variance in the data as a whole. The first and second principal components (PC1 and PC2) accounting for 56.14 and 21.44%, respectively, provided the correlation between the physical characteristic of rice grains and physicochemical properties of rice flours (Table 4).

The loading plot of the two first principal components described 78% of the variance in rice grain physical characteristics (i.e., RT and BMHT) and flour physicochemical properties variables (i.e., > 60 mesh %, 60-100 mesh %, PSI and damaged starch of rice flour) (Figure 1). PC1 highly correlated positively with RT, > 60 mesh %, milling

Table 5. Comparison among indica, japonica and waxy rice cultivars in terms of means and standard deviations of principal components

Principal	Means^{b}			Standard deviations		
component	Indica	Japonica	Waxy	Indica	Japonica	Waxy
PC 1 (56.14%)^{a}	-1.62^{a}	1.11^{a}	0.47^{a}	3.39	2.23	1.17
PC 2 (21.44%)	-1.39^{b}	0.64^{ab}	1.04^{a}	1.46	1.02	1.89
PC 3 (7.34%)	0.28^{a}	-0.46^{a}	0.46^{a}	1.03	0.87	1.00
PC 4 (5.47%)	0.11^{a}	-0.39^{a}	0.60^{a}	0.93	0.77	0.62
PC 5 (3.46%)	-0.39^{b}	-0.09^{b}	0.83^{a}	0.66	0.37	0.55

^{a}Percentage of variation explained by the component.

^{b}Means within row with different letters are different significantly at $p < 0.05$.

temperature of Stenvert hardness test, moisture and damaged starch of rice flour, and negatively correlated with BMHT, 60-100 mesh % and PSI. All of these attributes have already been shown to be highly correlated (Table 3). PC2 positively correlated with fat and ash contents, and negatively correlated with kernel shape and TKW. The results indicated that PC1 represented the mechanical properties and the endosperm texture of the rice grains, and PC1 may be a better estimate for rice hardness than these variables considered individually.

Crude protein content also contributed weakly to PC1 and PC2; however, it was not significantly correlated to any of the measures related to rice grain physical characteristics (i.e., RT and BMHT) (Table 3), a result which is in agreement with Goodman and Rao(2) but which does not support Juliano(1), who found that rice grain hardness was significantly related to protein content. Mestres *et al*.(26) summarized the dry milling properties of 18 corn types from Africa using a range of techniques and concluded that the ratio of hard to soft endosperm was correlated with kernel density but not with protein content or dry milling properties including semolina recovery.

Based on the results of PCA, the means of eigenvector values and standard deviations of the first 5 principal components are separated for indica, japonica and waxy rice cultivars (Table 5). Most of the mean differences among indica, japonica and waxy rice were not significant ($p <$ 0.05), but the standard deviation of the indica rice varieties was higher than japonica and waxy rice (Table 5). This variability reflected the higher heterogeneity of individual variety within indica than japonica and waxy rice cultivars. In previous studies, we reported that the hardness of indica rice grains negatively correlated with the ratio of chalkiness endosperm by stereoscopic zoom microscopy, but did not find the same within the japonica and waxy varieties(6). Chalkiness is due to grains containing more air spaces and having a disorganized cellular structure(27,28,29). This also confirmed previous results obtained with hardness measurement, particle size distribution and damaged starch.

The score plot of 14 rice samples were plotted on a plane with the percentages of variation associated with the PC1 and PC2 (Figure 2). The representation accounted for 78% of total variation; the other representations were less conclusive and will not be discussed. When comparing the loading and score plots, it was found that TG5, KS142, TC189, TG9 and TCS10 had high positive scores in PC1. Indeed, they presented higher RT and lower BMHT, giving relatively coarse flours with high damaged starch levels and high milling temperature of Stenvert hardness test (Table 1 and Table 2). Conversely, KSS7, TCS17 and TCN1 had high negative scores in PC1, giving higher value of BMHT, 60-100 mesh % and PSI. In addition, TGW1, TN9, TCW70, TG8 and TCN1 together had high positive scores in PC2. They were negatively related to the shape and TKW, but positively related to crude fat and ash contents. Thus, there is considerable direct evidence that the differences of rice grain physical characteristics (i.e., RT and BMHT) may play an important role in particle size distribution of rice flour, followed by chemical compositions in the present study.

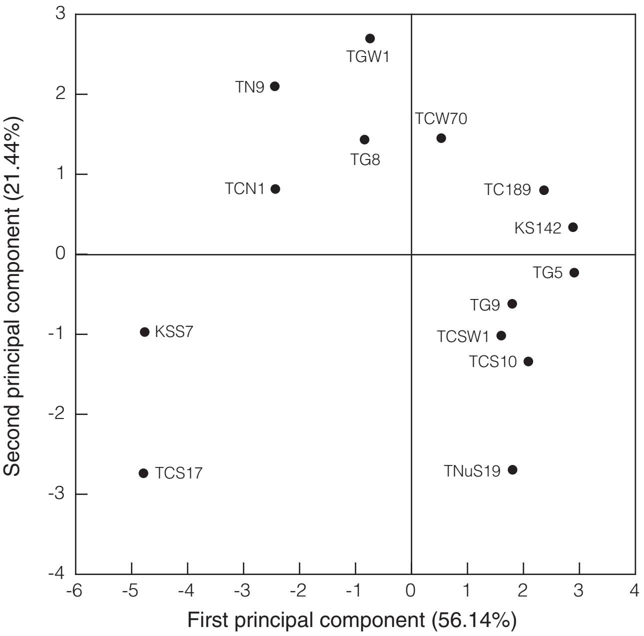

Figure 2. Score plot with first and second components of the principal component analysis of 14 rice cultivars.

CONCLUSION

Rice grain's physical characteristics were found to affect the particle size of rice flours, probably due to the revealed considerable structure heterogeneity among the 14 rice cultivars. Highly positive correlation was found among

RT, BMHT and physicochemical properties of rice flour (i.e., PSI, milling temperature of Stenvert hardness test and damaged starch of rice flour). The first principal component (PC1) was highly related to the RT, BMHT, PSI, milling temperature of Stenvert hardness test and damaged starch of rice flour. The second principal component (PC2) was positively correlated to fat and ash contents. However, the effect of protein content was intermediate between the PC1 and PC2. It was concluded that rice grain's physical characteristics (i.e., RT and BMHT) were major factors, followed by chemical compositions, affecting the particle size distribution of rice flour. Further investigation would be necessary for elucidation between grain textural properties, processing conditions and end product qualities.

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