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Using Multivariate Analysis Technique for Physicochemical Assessment of Indigenous Rice Varieties of Southern Thailand

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Abstract

Morphological variation of 72 indigenous rice varieties of southern Thailand was assessed with multivariate analysis technique basing on both of physical and chemical traits or known as physicochemical assessment. The 8 physical characteristics (hull color, brown rice color, brown rice shape, chalky grain, grain length, grain breadth, brown rice length and brown rice breadth) and 2 chemical properties (amylose content and elongation ratio) were evaluated for determining the typical pattern and classifying the groups of 72 Thai southern landraces of rice. The study results indicate that the grain characteristic of all rice varieties is long and the length and width of brown rice are medium. Similarly, the amylose content is medium so it produces a soft cooking. The first 4 PCs (grain length, brown rice characteristics, brown rice color and amylose content) of factor analysis explain 66.8% of the total variability. The hierarchical cluster analysis capably classifies 72 rice accessions into 2 groups depending on the derived 4 PCs. Both clusters are the same of physical characteristics but the chemical properties are distinct only in the aspect of amylose content. Additionally, the Hotelling's T^2 statistic also confirms that these 2 obtained clusters are significantly different.

Keywords: Indigenous Rice Varieties of Southern Thailand, Multivariate Analysis, Physicochemical Assessment

INTRODUCTION

Rice is one of the most important crops in the world because over half the world's population consumes rice as a major staple food. In addition, rice is cultivated in many countries so it plays an important role in agricultural economics. Total demand for rice in the world is estimated increase at about 1% per annum from 2001 to 2025. (Maclean et al., 2002). Asia is the largest source provided rice more than 90% of the world. Among major producing countries in this region, Thailand is the second largest rice exporting country in the world next below India (Arunmas, 2017). Rice can grow and adapt to a broad range of climatic conditions. It is thus capably cultivated in all parts through Thailand ranging from lowland and upland areas which covered about 65 million rais of country (Thai Exporter Association, 2017). The total rice lands in country are approximately more than 50% in the northeast, 40% in the north and central and the leavings in the south. Nowadays there are two types of rice varieties mainly harvested in Thailand. The first is local varieties which have long been traditionally observed, selected and collected by agriculturists so they were named for geographical area such as Khao Leuang Patew Chumpon, Khao Jek Chuey Sao Hai, etc. The other type is new hybrid varieties which resulted from a cross-breeding among existent varieties like Thai Hom Mali 105, Thung Kula Jasmine Rice, etc. Selecting, improving and developing of breeds are all encouraged and patronized by the government. Difference between these two variety types is judged from rice quality. Preference of rice consumer depends on the evaluation of quality attributes which is determined not only by physical and chemical properties of grain, but also by aspects related to the appearance after cooking like texture, taste and aroma.

Presently, there are many researches related to the concept of improving rice quality without the GMOs (Genetically Modified Organisms) technique. One of possible alternatives is finding the existing landraces of potential rice to develop the new

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variety as desirable traits because the traditional rice varieties provide high nutritional value, medicinal properties and ability of resisting severe weather conditions, diseases and pests. The southern region of Thailand is an important resource largely produced the indigenous rice up to 4,000 varieties (Bureau of Rice Research and Development, 2007). However, there are a lot more of cultivars remain unexplored. Information and physicochemical characterization about indigenous rice varieties of southern Thailand is insufficient so many researchers still have been continually working on this study for further development. Many abroad workers reported using agro-morphological makers in the characterization of rice variety diversity with multivariate analysis technique, for example; Xie et. al (2007), Diako et. al (2011), Rekha et. al (2011), Sinha & Mishra (2013), Worede et. al (2014), Wijayawardhana et. al (2015) and Islam et. al (2018), etc. It is deficient works which is related to the local rice varieties in Thailand, for example; Promsomboon & Prosomboon (2016) and Panomjan et. al (2016). It is essential for the present study that not only to conserve the existing indigenous rice varieties of southern Thailand but also to explore the physicochemical characteristics to capture such significant agro-morphological traits. Multivariate analysis technique is then utilized and applied to determine the typical pattern and classify the groups of 72 Thai southern landraces of rice. The authorizers finally may use these findings for quality improvement of traditional rice landraces.

MATERIALS AND METHODS

The present study was carried out using 72 landraces of rice cultivars collected from Phatthalung Rice Research Center, The Rice Department of the Ministry of Agriculture and Cooperative of Thailand. It supplies not only physical characteristics but also chemical properties. The 8 physical characteristics were gathered as 4 qualitative variables; hull color (straw, brown, yellowish purple), brown rice color (white, yellowish red), brown rice shape (slender, quite round, round), and chalky grain (little, moderate to high) and 4 quantitative variables in unit of millimeter; grain length, grain breadth, brown rice length and brown rice breadth. The 2 quantitative variables of chemical properties; percentage of amylose content and time of elongation ratio, were also provided. To assess the physicochemical traits of 72 rice accessions, the mainly statistical steps were then applied respectively.

1. Descriptive statistics with minimum, maximum, mean and standard error of mean (SE.) were computed to study general characteristic of indigenous rice varieties of southern Thailand for both quantitatively physical and chemical parameters.
2. Four statistical hypotheses were tested to examine the association among all 10 physicochemical characters.

2.1) Evaluating relationship between each pair of quantitative variables with Pearson correlation.
2.2) Evaluating relationship between each pair of qualitatively physical variables with Pearson chi-squared test.
2.3) Scaling connection between one quantitatively dependent variable and one qualitatively independent variable categorized 2 groups (brown rice color and chalky grain) with z test.
2.4) Measuring correlation between one quantitatively dependent variable and one qualitatively independent variable categorized 3 groups (hull color and brown rice shape) with ANOVA.

3. Three techniques of multivariate analysis were utilized for classifying 72 landraces of rice.

3.1) Determining significant variables in categorizing all rice accessions with factor analysis.
3.2) Grouping all rice accessions based on the derived crucial variables from factor analysis with cluster analysis.
3.3) Comparing both differences of physical characteristics and chemical properties among the derived groups from cluster analysis with Hotelling's T^2 statistic if obtaining 2 groups of all rice accessions, otherwise MANOVA is used instead.

RESULTS

The results of this study consequently show as follows.

1. The physicochemical assessment of 72 indigenous rice varieties of southern Thailand was evaluated with descriptive statistics as of Table 1.

Table 1: Descriptive statistics of 72 indigenous rice varieties of southern Thailand

Parameter	Minimum	Maximum	Mean	SE.
Physical characteristics				
Grain length	5.82	9.82	8.6921	0.0894
Grain breadth	2.12	2.88	2.4596	0.0203
Brown rice length	4.10	7.65	6.4594	0.0670
Brown rice breadth	1.17	2.68	2.2757	0.0248
Chemical Properties				
Amylose content	6.50	28.14	24.3420	0.4140
Elongation ratio	1.45	2.10	1.7737	0.0183

Regarding with the appraisement of shape and size seed for rough rice, brown rice and milled rice (Webb, 1991), it reveals that the general physical characteristics for grain character of all rice varieties is long and the length and width of brown rice are medium. It also exhibits that the amylose content is medium comparing with the classification of rice type (Rice Research and Development Division, The Rice Department of the Ministry of Agriculture and Cooperative of Thailand, 2016) so its feature of cooked rice is quite loose but not firm.

2. To examine the association among all 10 physicochemical characters, four following statistical hypotheses were tested.

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2.1) Most pairs of quantitative variables are linear relationship based on very small p-values (<0.01) of Pearson correlation except 5 pairs of these variables; amylose content and the length and breadth of grain, amylose content and the length and breadth of brown rice and finally grain length and brown rice breadth.
2.2) All p-values of Pearson chi-squared test are really big. Thus, there are no relationship between each pair of qualitatively physical variables.
2.3) There is only one p-value of z test between grain breadth and brown rice color less than 0.05. It states that mean of grain breadth between brown rice of white and of yellowish red color are different.
2.4) For physical characteristics, mean of brown rice length among all 3 hull colors (straw, brown, yellowish purple) are dissimilar. Also, mean of grain length, grain breadth, brown rice length and brown rice breadth among all 3 shapes of brown rice (slender, quite round, round) are distinct. For chemical properties, there are different mean of elongation ratios among all 3 hull colors (straw, brown, yellowish purple) and all 3 shapes of brown rice (slender, quite round, round).
3. To classify 72 landraces of rice, three respective techniques of multivariate analysis were utilized.
3.1) Factor analysis with principal component extraction was employed to discover the importance and contribution of each principal component (PC) to total variance. Kaiser (1958) suggested an appropriate number of PCs is setting equal to the number of eigenvalue which are greater than 1 or nearly to 1. The first 4 PCs in factor analysis contributes 66.8% with eigenvalue greater than 1 among total variability for 10 physicochemical traits of 72 landraces of rice are represented in Table 2.

Table 2: Eigenvalue, proportion of variation and cumulative proportion of variation for each PC

PC	Eigenvalue	Proportion of variation	Cumulative proportion of variation
PC 1	3.102	0.310	0.310
PC 2	1.312	0.131	0.441
PC 3	1.203	0.120	0.562
PC 4	1.067	0.107	0.668
PC 5	0.824	0.082	0.751
PC 6	0.793	0.079	0.830
PC 7	0.555	0.055	0.885
PC 8	0.483	0.048	0.934
PC 9	0.437	0.044	0.977
PC 10	0.225	0.023	1.000

Sometime the original loadings of factors may not be easily interpretable so it is usually to rotate them in practice until a simpler structure is obtained (Johnson & Wichern, 2007). Varimax, one of rotation methods, was then applied. The varimax rotated factor loadings were estimated in Table 3.

Table 3: Estimated varimax rotated loadings of 4 factors

Variable	FA 1	FA 2	FA 3	FA 4
Hull color	-0.470	0.088	0.574	-0.053
Brown rice color	0.228	0.136	0.823	-0.050
Brown rice shape	0.152	-0.754	-0.106	-0.053
Chalky grain	-0.402	-0.477	0.389	0.295
Grain length	-0.815	0.100	-0.026	-0.214
Grain breadth	0.351	-0.523	-0.289	-0.050
Brown rice length	-0.787	0.435	-0.103	0.037
Brown rice breadth	0.141	-0.804	-0.031	0.075
Amylose content	0.084	0.072	-0.004	0.904
Elongation ratio	0.450	-0.360	-0.243	0.467

Liu et al. (2003) classified factor loadings in absolute value of greater than 0.75 as strong, 0.50-0.75 as moderate and 0.3-0.5 as weak. Basing on strong value, it clearly states as follows.

Factor 1 (FA1) denotes as grain length and brown rice length with 31.00% of total variance.
Factor 2 (FA2) denotes as characteristics of brown rice in dimension of shape and width with 13.10% of total variance.
Factor 3 (FA3) denotes as brown rice color with 12.00% of total variance.
Factor 4 (FA4) denotes as amylose content with 10.70% of total variance.

3.2) The hierarchical technique of cluster analysis apparently grouped all rice accessions into two clusters as seeing of dendogram in Fig. 1.

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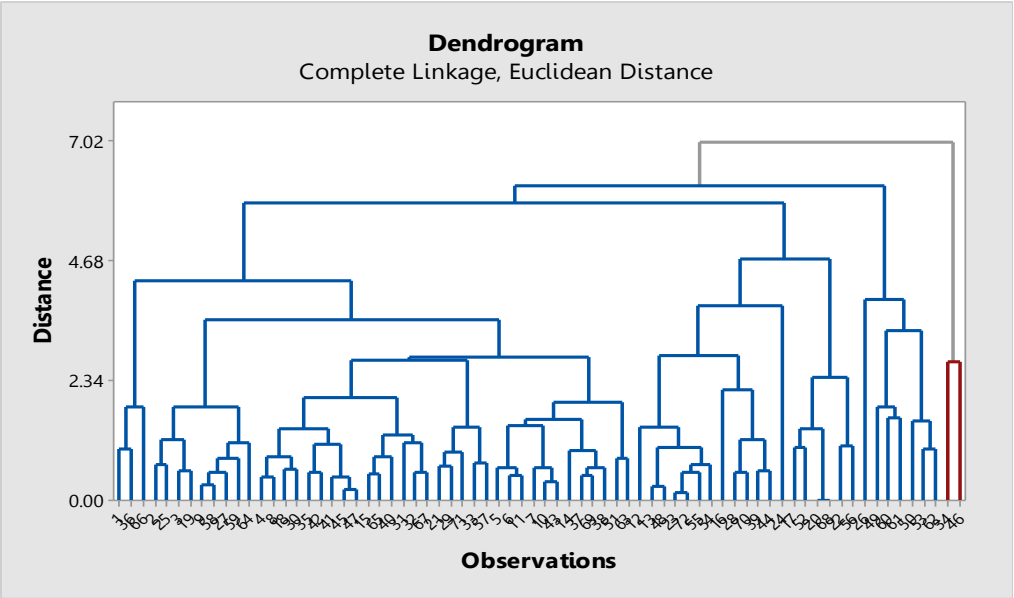

Fig. 1: Dendogram of rice accessions with hierarchical technique

Cluster 1 contains about 70 cultivars. The two remainder of landraces rice are in cluster 2; Niaw Look Gah and Geu Se Khao. Both clusters of all rice accessions are really similar in physical characteristics of grain and brown rice. However, the chemical properties of these two clusters are different in the aspect of amylose content. Cluster 1 represents rice varieties with medium amylose whose feature of cooked rice is quite loose. Cluster 2 stands for rice varieties with low amylose whose feature of cooked rice is tenderly viscous.

3.3) The Hotelling's T^2 statistic is computed as $T^2 = 3{,}465.99$ when the variance-covariance matrix of 4 physicochemical factors between 2 clusters of all rice accessions are equal, otherwise $T^2 = 54.43$. The critical value of the test is 14.49 at 0.05 significant level. Therefore, there is the Hotelling's T^2 statistic capably explains there is mean difference between 2 clusters of all rice accessions based on 4 physicochemical factors; grain length, length and color of brown rice and amylose content.

CONCLUSION AND DISCUSSION

Grain length, brown rice length, brown rice shape, brown rice width, brown rice color and amylase content are important physicochemical traits in differentiating the groups of indigenous rice varieties of southern Thailand. Principal component extraction identifies 4 factors substantially affecting all rice accessions also these factors capably explained 66.8% of total variance. That implies 3 major source categories influencing on all rice accessions are respectively came from grain length and the characters of brown rice in dimension of length, shape and color (FA1-FA3: 56.10%) and the source accounted for amylose content (FA4: 10.70%). These are confirmed with significant association measurement among physicochemical characters; Pearson correlation between grain and brown rice length, ANOVA of grain length, brown rice length and brown rice width based on the brown rice shape. The typical patterns of two clusters classified by cluster analysis are generally the same physical characteristics but different in chemical properties of amylose content. The one with lower amylose content tends to be sticky, moist and better testing. Similar results were reported by Diako et al. (2011), Moukoumbi et al. (2011) and Tehrim et al. (2012) which were notified that grain length and amylose content are significantly basic physicochemical characteristics for assessment of rice accessions. Therefore, morphological traits are used as a preliminary evaluation tool as a common approach for assessing variability among physicochemical distinguishable rice accessions. The authorizers may utilize and apply these findings in future study for improving quality of indigenous rice varieties of southern Thailand.

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