Vietnam Journal of Science and Technology ***60*** *(5) (2022) 767-784*

doi:10.15625/2525-2518/14447

PHYSICAL AND CHEMICAL PROPERTIES OF RICE VARIETIES GROWN IN MEKONG DELTA

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Received: 6 August 2021; Accepted for publication: 16 September 2022

Abstract. 125 rice samples of 10 rice varieties (Daithom8, IR50404, Jasmine85, DS1, OM4900, OM5451, OM6976, OM7347, ML202, Glutinous rice) collected from 10 provinces in the Mekong Delta were not different in grain length ranging from medium to long and were mainly tapered in shape. Except for DS1, because of the *Japonica* variety, it is round in shape. Their chemical ingredients slightly differed between varieties, but there was a clear difference in amylose content, according to which these rice samples were divided into 4 groups: samples with very low amylose content ranging from 3 to 9 %, accounting for 3 % of the total samples and belonging to the Glutinous rice variety; samples with medium amylose content (20 - 25 %), accounting for 29 % of the total samples and mainly belonging to varieties Jasmine85 and OM5451; samples with high amylose content (≥ 25 %), accounting for 20 % of the total samples and belonging to varieties IR50404, ML202, and OM6976; and samples with low amylose content (9 - 20 %), accounting for 48 % of the total samples and belonging to the remaining varieties. Based on physical and chemical properties, the rice varieties of 125 survey samples were classified into 3 groups with specific characteristics. In group 1, samples were characterized by particle size, particle shape, moisture, lipid and ash content; in group 2, samples were characterized by properties such as starch and amylose content; group 3 was characterized by width, protein and amylopectin. In addition, rice samples were divided into 3 groups based on growing location and physicochemical properties.

Keywords: Mekong delta, rice quality, chemical and physical properties, rice.

Classification numbers: 1.4.4, 1.4.5

1. INTRODUCTION

With an annual output of more than 505 million tons, rice is the main source of human food after wheat. According to statistics of the United States Agricultural Association (USDA), Viet Nam is forecasted to be the world's second largest rice exporter after India in 2021. Viet Nam has 3 main rice growing areas: the Red River Delta, the Central Coastal Delta, and the Mekong Delta. In particular, the Mekong Delta is the largest rice area in Viet Nam in terms of both area and yield [1]. Every year, Viet Nam exports rice to more than 150 countries around the world, of which, the Asian market always ranks the first, especially the Philippines accounting for 33.9 %, followed by China (19 %) and Ghana (10 %). Viet Nam's total rice export output in 2020 reached 6.25 million tons (According to the General Department of Customs, 2021) [2].

Viet Nam has potentials and strengths in the field of rice production and export in the world, and the quality of Viet Nam's rice is gradually improving. However, because the quality is not guaranteed, the price of Vietnamese rice in the global market is unstable and very low compared to other rice exporting countries in the world (According to FAO rice price update statistics, 2020) [3].

Rice qualities are characterized by sensory, physical and chemical properties and market demand. Mestres *et al.* showed the relationship between sensory, physical and chemical properties of rice [4]. Usman Ahmad *et al.* (2017) conducted a study to control Catahoula rice quality by adjusting milling level and storage temperature. The results showed that the physicochemical and organoleptic properties of rice were changed with different degrees of milling and storage temperature [5]. Another study investigating the change in physicochemical properties during storage at different temperature ranges was conducted by Chan-Eun Park *et al.* (2012). The obtained results showed that at high storage temperature, the physicochemical and sensory properties changed more than the initial [6]. Jean-Francois Meullenet *et al.* (2000) investigated the effect of post-harvest factors (crude rice moisture, storage temperature and storage time) on sensory quality of some cultivated rice varieties in Arkansas with a panel of experts. A list of 8 texture-related sensorial properties (lip adhesion, hardness, mass adhesion, tooth adhesion, roughness, etc.) and 6 flavor attributes (sulfur, grain, metal, starch, cardboard, etc.) was identified as having an important role in evaluating the properties of rice [7]. Yang Xiao-yu *et al.* (2013) analyzed 16 commercial *Japonica* rice samples from Northeast China and Jiangsu Province and reported significant differences in physicochemical properties such as chalky grain rate, amylose and protein contents, and pasting properties between the samples in two main areas [8]. Northeastern rice contained more short-chain amylopectin than Jiangsu rice, but in the terms of sensory quality, the samples were evaluated equally. The former authors hypothesized that the difference was due to growing conditions and that the amylose and protein contents were not representative of the overall sensory quality. The rice grain quality and yield were also thought to be influenced by factors such as variety, climate, season, and grown conditions [9].

Numerous studies on rice characteristics have shown a correlation between chemical contents, physical properties and structural and sensory properties of rice, one of the criteria influencing consumer choice [10 - 14]. Low amylose content resulted in low hardness and high stickiness, as well as shorter gel-times and approximate cooking time in 10 Italian rice varieties and 15 domestic and imported jasmine rice samples in Texas [15, 16]. Protein and fat content significantly affected the appearance of jasmine rice [16]. The sensory quality of *Japonica* rice varieties harvested in Xiangshui and Hangzhou (China) was found to be negatively correlated with protein content and positively correlated with gel hardness. Therefore, the growing location was known to be an important factor in determining sensory quality [11]. Furthermore, knowledge of physical and physicochemical properties is essential to design appropriate structures for storage and other equipment for drying, harvesting, planting, handling, and sorting [17]. In Viet Nam, there have also been a number of studies evaluating the quality of Vietnamese rice and the influence of processing factors and varieties on yield and quality [18, 19]. However, the relationships between physicochemical and sensory properties and the variety and harvesting location of Vietnamese rice had not yet been published.

This work aimed to study the influence of variety and growing location on the physical and chemical properties and the relationships between these factors in order to determine the traceability basis in future research.

2. MATERIALS AND METHODS

2.1. Materials

Rice samples: A 20 kg lot of each of the 125 paddy samples was collected from 10 provinces with 10 varieties planted in the Mekong Delta including14 samples from An Giang, 14 samples from Dong Thap, 10 samples from Long An, 25 samples from Vinh Long, 6 samples from Can Tho, 5 samples from Soc Trang, 14 samples from Tra Vinh, 7 samples from Tien Giang, 11 samples from Hau Giang, and 19 samples from Kien Giang (Details are shown in Table 1). Samples were collected in the field immediately after harvesting. The paddy was naturally dried in the sun to a moisture content of 14 %, then dehusked in a Model KL1000 dehusking machine (VT-MXX07). The brown rice obtained was polished in a single pass rice pearler with the degree of whiteness being set between "low" and "medium". The rice was kept under ambient conditions for 3 days. The dried samples were referenced and stored at 25 ^{o}C during this study for 3 months.

Table 1. Information of varieties by harvest location of rice grain samples.

Variety	An Giang	Can Tho	Dong Thap	Hau Giang	Kien Giang	Long An	Soc Trang	Tien Giang	Tra Vinh	Vinh Long
Dai Thom 8 (Daithom)	3	-	2	-	3	2	2	3	1	1
Jasmine85 (JAS)	-	5	-	-	4	-	-	2	-	-
OM4900 (OM4)	-	-	2	-	6	2	-	-	-	1
OM5451 (OM5)	1	-	1	10	4	1	3	-	1	12
OM6976 (OM6)	3	-	-	-	-	-	-	-	-	2
OM7347 (OM7)	-	-	2	1	-	2	-	1	-	1
ML202 (ML)	-	-	-	-	-	-	-	-	7	-
IR50404 (IR5)	3	-	3	-	2	-	-	1	5	8
Glutinous	3	1	-	-	-	3	-	-	-	-
DS1	1	-	4	-	-	-	-	-	-	-
(-) None										

2.2. Methods

Size and shape: 100 grains of rice from each sample were selected at random. Selected grains must be intact, not broken or deformed. The length and width of the grains are determined using a caliper with an accuracy of 0.1 cm. The shape of the rice samples was determined based on the L/W ratio [20]:

$$\text{Ratio}\frac{\text{L}}{\text{W}} = \frac{\text{Grain length}}{\text{Grain width}}$$

The size and shape of the rice is classified according to the IRRI scale [21].

Sample preparation: The rice grain samples were finely ground and passed through a No25 mesh sieve.

Moisture: Moisture content was determined based on ISO 7712:2009 [22].

Ash: Ash content was measured according to TCVN 8124:2009 [23].

Starch: Rice starch was hydrolyzed to reducing sugars with HCl 6 %. The reducing sugar content was determined by spectrophotometric method at 540 nm, after being complexed with dinitro salicylic acid reagent. D-glucose was used as the standard. The conversion factor of glucose-starch was 0.9 [24].

Amylose: Amylose content was determined based on AACCI Approved Method 62-03.01 using pure potato amylose as the standard amylose with slightly modifications. 100 mg of rice flour sample was mixed into 1 mL of 95 % ethanol and 9 mL of 1 M NaOH at 80 ^oC for 15 minutes. The sample was cooled to room temperature and diluted to 100 mL with distilled water. 2.5 mL of the sample was placed in a 50 mL volumetric flask. Next, 0.5 mL of 1 M acetic acid and 1 mL of 0.2 % iodine in 2 % KI were added. Then, the solution was made up to volume with distilled water. The sample was measured for absorbance at 620 nm for 20 minutes after mixing. [25].

Protein: Total nitrogen was determined by the Kjeldahl method according to TCVN 8125:2015; a nitrogen-protein conversion factor of 5.95 was used to calculate the total protein content of rice.

Lipid: Lipid content was calculated by Soxhlet extraction with petroleum ether according to TCVN 6555:2017.

2.3. Statistical analysis

Each experiment was repeated 3 times; the results were the mean of triplicates. Correlation analysis, two-way ANOVA (analysis of variance), and PCA (principal component analysis) were conducted in the FactoMineR package developed on R software version 4.1.1. The significance level in the study was 0.05.

3. RESULTS AND DISCUSSION

Shape and size. Table 2 shows the results of shape and size of rice samples in the Mekong Delta. The rice grain length varied from 5.47 to 6.99 mm. Rice grown in the Mekong Delta accounted for 96 % of the long grain rice, including varieties Daithom, IR5, JAS, ML, Glutinous, OM4, OM5, and OM7, mostly long grain rice. There were 4 % of rice samples with short, round grain size like DS1. This is a pure rice variety, *Japonica* sub-species imported and selected by the Agricultural Genetics Institute , which is one of the high-quality Japanese rice varieties, with round grain, white and flexible rice. Most rice varieties had a slender shape, except for ML and DS1, which were medium. Compared with Thai rice varieties, it can be seen that the studied samples were shorter in length and most had similar slender shapes [27, 28]. The grain dimension is a genetically impacted character and not greatly affected by management practices [29].

Table 2. Size and shape of rice grains by varieties.

Variety	Length (mm)	Width (mm)	L/W	Size classification	Shape classification
Daithom8	6.84 ± 0.20ab	2.05 ± 0.13bc	3.35 ± 0.26a	Long	Slender
Jasmine85	6.99 ± 0.17a	2.12 ± 0.08bc	3.29 ± 0.17a	Long	Slender
OM4	6.87 ± 0.19ab	2.11 ± 0.15bc	3.28 ± 0.31a	Long	Slender
OM5	6.66 ± 0.31abc	2.01 ± 0.15c	3.33 ± 0.42a	Long	Slender
OM6	6.61 ± 0.86abc	2.23 ± 0.43ab	3.10 ± 0.82ab	Long	Slender
OM7	6.51 ± 0.88bc	2.22 ± 0.26ab	2.99 ± 0.61ab	Medium	Medium
ML	6.20 ± 0.59c	2.21 ± 0.15b	2.82 ± 0.42b	Medium	Medium
IR5	6.49 ± 0.59c	2.12 ± 0.24bc	3.10 ± 0.47ab	Medium	Slender
Glutinous	6.53 ± 0.40abc	2.12 ± 0.29bc	3.13 ± 0.50ab	Medium	Slender
DS1	5.47 ± 1.04d	2.46 ± 0.51a	2.39 ± 0.99b	Short	Medium
Thai rice varieties (Fofana, M. *et al*. (2011)) [28]					
Elephant	7.18	1.98	3.63	Long	Slender
Gino	7.16	2.05	3.49	Long	Slender
Sawana	7.23	2.00	3.46	Long	Slender
Special rice	7.11	2.04	3.49	Long	Slender
Sultana	7.20	2.07	3.49	Long	Slender

Values with different letters in a column are significantly different ($p < 0.05$).

Moisture. According to Viet Nam standards 11888 : 2017 - white rice standard and CODEX STAN 198–1995, the required or standard moisture content for rice products is about 14.0 - 14.5 % [30,31]. Figure 1 shows that the moisture content of rice samples after sun drying in the Mekong Delta ranged from 10.19 % to 14.0 %, within the permissible range, even lower than the standard. It also shows that OM4 variety had the highest moisture content (13.21 %) and DS1 variety was the lowest moisture content (12.13 %). The moisture content of the studied rice varieties was lower than that of some other rice varieties of Viet Nam (12.8 - 15.2 %) and Japan (13.8 - 14.4 %) in the study of Tran, U. T. *et al.* (2001) [14]. Figure 2 demonstrates that the moisture content of rice samples was highest in Kien Giang and lowest in Soc Trang, at 12.99 and 11.77 %, respectively. The moisture content of samples in the same province fluctuated greatly. Moisture content is a property that is less affected by variety, but the difference is due to factors such as drying methods and parameters, storage conditions, and moisture content of paddy after harvest [32,33]. According to Dillahunty *et al.* (2000), when the moisture content of grains was less than 14 %, the respiratory intensity was insignificant; conversely, at higher humidity (greater than 14 %), the respiration rate was higher [34]. Moisture below 14 % is also required to prevent mold growth [32].

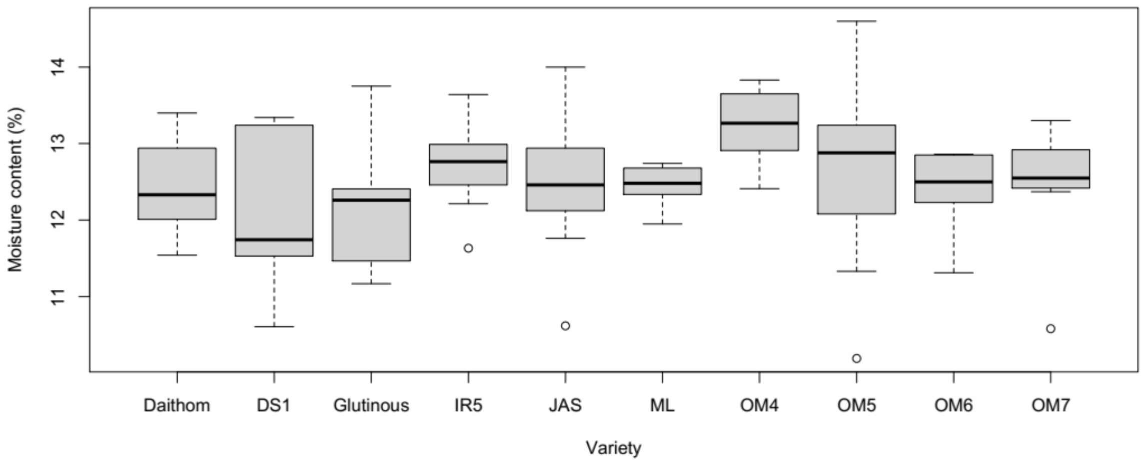

Figure 1. Moisture content by varieties.

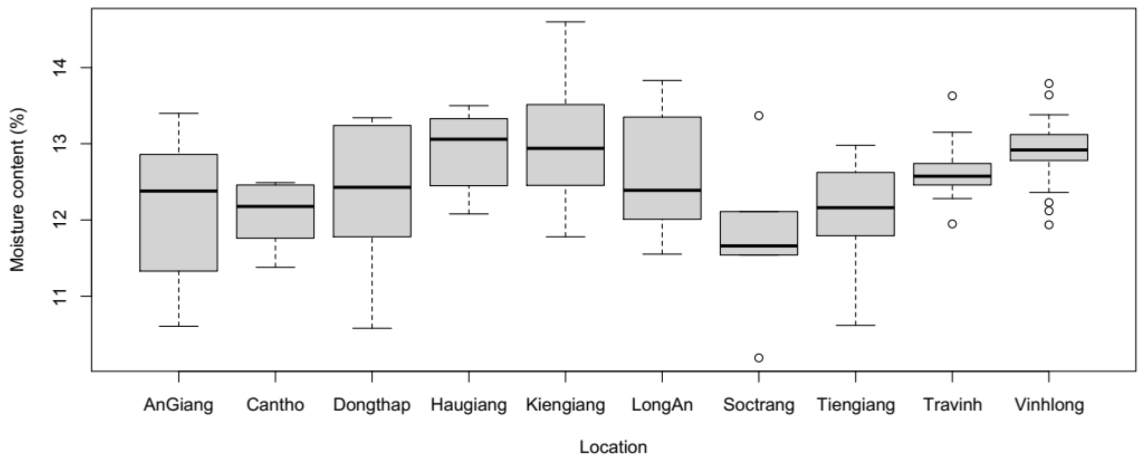

Figure 2. Moisture content by locations.

Ash. Figures 3 and 4 indicate that the ash content of rice samples from the Mekong Delta was about 0.20 - 1.04 %. In Figure 3, the highest was ML and IR50404 varieties, 0.55 and 0.54 %, respectively, and the lowest was OM6 and glutinous varieties, 0.38 and 0.39 %, respectively. However, there was no significant difference between the samples by variety. E. Adu-Kwarteng *et al.* (2003) reported that the milling and polishing process had a significant effect on the ash content of rice [35]. Since the husk and bran layer contains many minerals, if the rice is not milled well, flecks of bran remain attached to the grain, affecting the ash content [35].

Furthermore, Figure 4 presents the ash content of rice samples by growing location. These results showed that there was no statistically significant difference between the samples by growing location. However, there were some slight differences in some rice varieties, particularly Daithom, in which the mean ash content of samples in Long An was only 0.38 %, while it ranged between 0.5 and 0.58 % in other provinces. For OM5 variety, the average ash content of samples in Hau Giang was 0.55 %, while it was 0.47 % in Vinh Long. Besides, there was also no significant difference in ash content between samples grown in the same province. Shayo *et al.* (2009) reported that the ash content varied according to the planting location. The more minerals in the soil, the higher the ash content in rice. The high ash content also greatly affects the organoleptic quality of the rice, causing the rice to darken or have a metallic taste [36]. In general, the ash content results obtained were completely consistent with the findings of Juliano (1985) and Nishiwaki, M. (2018), when most of the ash content obtained was in the range of 0.2 - 0.6 % [37, 38].

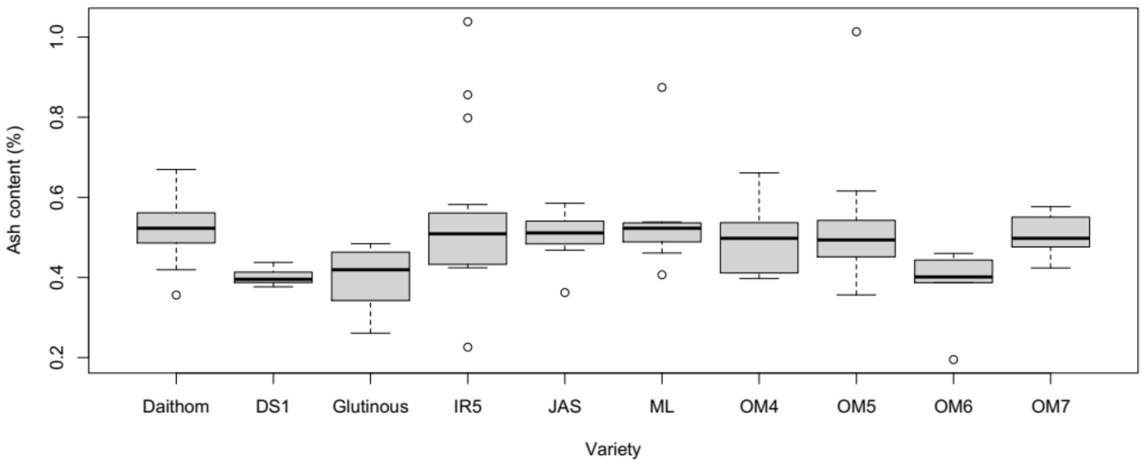

Figure 3. Ash content by varieties.

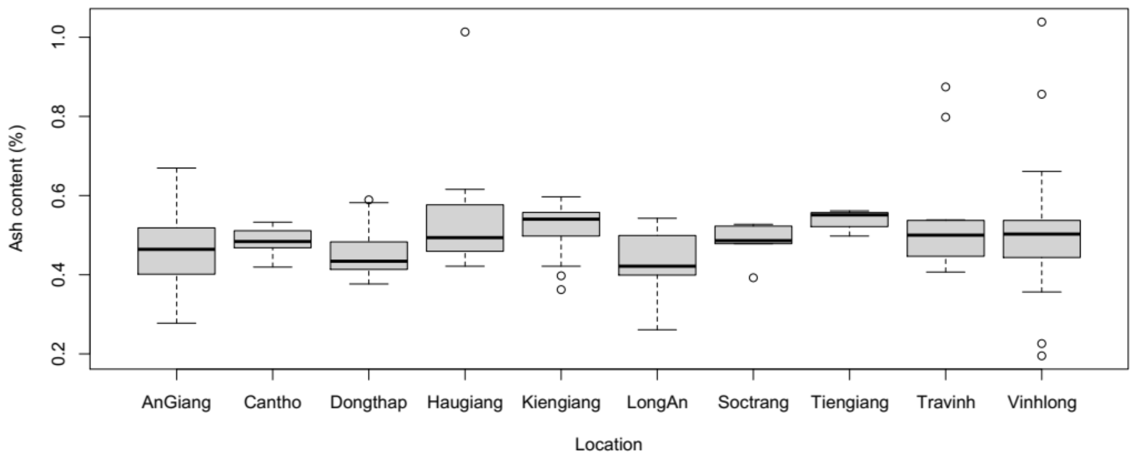

Figure 4. Ash content by locations.

Protein. Figures 5 and 6 shows that the protein content of rice from the Mekong Delta ranged from 6.25 to 9.42 %. The protein content of the samples in this study was comparable to other Vietnamese rice varieties studied by Tran, U. T. *et al*. (2001) (average was 7.8 %, ranged from 6.6 to 10.5 %) [14]. Figure 5 shows that Jasmine85 variety (JAS) had the highest average protein content of about 8.6 %, which was significantly different from other varieties and also higher than the Jasmine rice samples imported from Thailand into Texas (6 - 7 %) [16]. The protein content of rice from the Mekong Delta region of Viet Nam was comparable to that of some rice varieties from Thailand and Japan, but lower than that of some new rice varieties developed by the Africa Rice Center [14,28]. With *Japonica* rice cultivars, DS1, the protein content (ranging from 7.7 to 8.46 %) was similar to that of the *Japonica* varieties grown in China under nitrogen-free fertilizer conditions (7.80 - 8.65 %) [39].

Furthermore, Figure 6 shows significant differences between samples in different geographic areas with a significance level of 5 %. The highest was in Can Tho province, because it mainly consisted of JAS samples. The lowest among the provinces was Vinh Long, mainly samples belonging to the OM series and IR5 variety. Wopereis-Pura *et al.* (2002) and Leesawatwong *et al.* (2005) demonstrated that soil and farming factors, particularly fertilizers, had a significant impact on rice protein content. The higher the nitrogen content of fertilizers, the higher the protein content [40, 41]. Crude protein content has been shown to have a negative impact on appearance, flavor, and stickiness of cooked rice, as well as the aroma and flavor of sake [42, 43]. Cooked rice with a high protein content has a high hardness, elasticity, and a decreased taste [12].

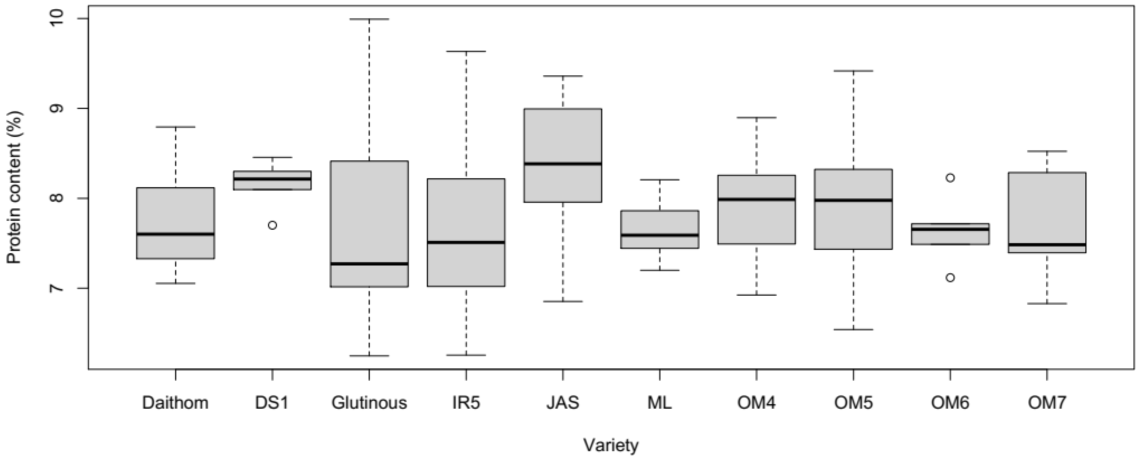

Figure 5. Protein content by varieties.

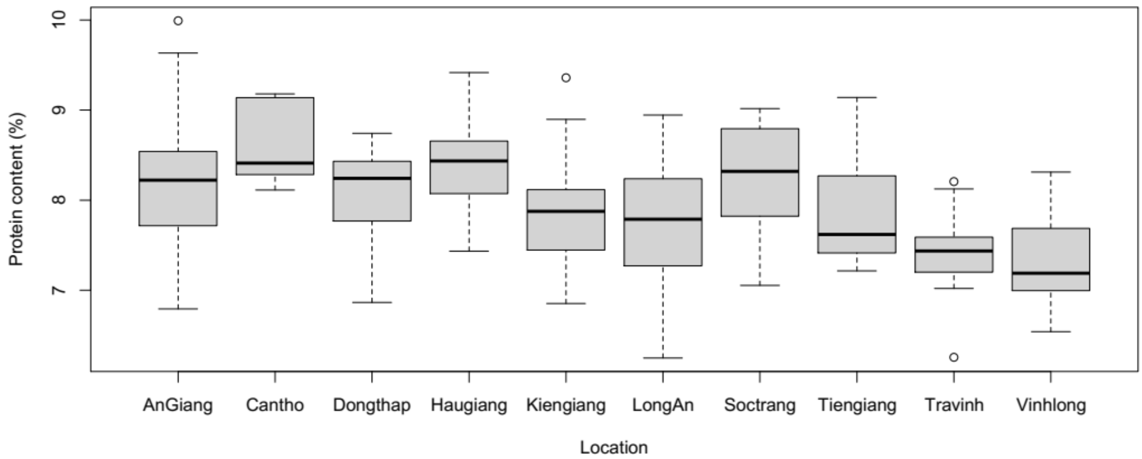

Figure 6. Protein content by locations.

Amylose. It can be seen from Figures 7 and 8 that the amylose content of rice grain from the Mekong Delta region of Viet Nam ranged from 3.17 to 35.39 %. The amylose content of glutinous, IR5, and ML varieties differed significantly from that of other varieties. Glutinous variety had the lowest amylose content (7.51 %), IR5 and ML varieties had the highest (26.48 and 27.99 %, respectively). Rice from Tra Vinh and Vinh Long had significantly higher amylose content than that of the other provinces, at 28.45 and 22.05 %, respectively. The findings revealed that there was a statistical difference in amylose content between rice varieties. Rice was divided into 5 groups based on amylose content, namely waxy (glutinous) (0 - 2 %), very low (5 - 12 %), low (12 - 20 %), intermediate (20 - 25 %), and high (25 - 35 %) [26]. Thus from Figures 7 and 8, rice varieties grown in the Mekong Delta region belonged to 4 out of 5 groups mentioned above. Seven samples of glutinous rice in this study contained less than 12 % amylose content, 3 samples had waxy to very low amylose content (2 - 5 %), 3 samples had very low amylose content (5 - 12 %), and 1 sample had low amylose content. These samples had higher amylose content than Vietnamese glutinous rice samples reported in Tran, U. T. *et al.* (2001), 3.1 - 7.5 % and 2 - 3 %, respectively [14]. This result was consistent with the study by Tuong, N. T. *et al*. (2005) who found that some glutinous varieties grown in the Melkong Delta (Ba Gia, La He, Ruoi, Vo Vang) had amylose content ranging from 4 to 9 % [44]. The findings agreed with those of Bui Chi Buu *et al*. (2000), who revealed that some glutinous varieties can degrade due to random mutations or hybridization with other rice varieties during the production process, such as Ba Bong and La Xanh glutinous varieties. As a result, the amylose content was greater than 2 - 5 %, and possibly as high as 9 - 11 % [44,45]. Samples in the intermediate range (20 - 25 %), such as JAS and OM5, accounted for 19 % of the total. IR5 and ML, accounting for 20 % of the samples, belonged to the group with high amylose content (25 - 35 %) and the remaining varieties (48 %) had low amylose content (12 - 20 %). Compared to Tran, U. T. *et al*. (2001), non-glutinous rice varieties in both studies had equal amylose content, ranging from 17 to 35 % [14]. The results were partially similar to those reported by Juliano *et al*. (1993) who found that Vietnamese rice varieties had a high amylose content of more than 20 %, except for some glutinous rice varieties [18]. However, there were many rice varieties with higher amylopectin content than the results in research of Juliano *et al.* (1993). This is due to the fact that rice with a high amylose content has a dry and hard texture, whereas rice with a low amylose content has a sticky, soft, and moist texture [46]. As a result, rice with a high amylopectin content is frequently preferred in many markets, hence more and more varieties of high amylopectin have been developed [13,14].

From Figure 8, it is shown that growing location affected the amylose content of rice varieties. In the same province, amylose content of rice samples fluctuated strongly, except for Can Tho. This was because the amylose content was highly dependent on the rice variety. The research also found that with the same rice variety but grown in different regions, the amylose content was also different. Specifically, for Daithom variety, the amylose content ranged from 22 to 26 % in Long An samples, 14 - 20 % in An Giang, Dong Thap, Kien Giang, and Soc Trang samples, and 19 - 22 % in Tien Giang samples. With IR5 variety, the amylose content of samples from Dong Thap was 15 - 22 %, while that of the remaining provinces ranged from 19 to 32 %. The study found differences in glutinous rice varieties, with the average amylose content of samples from An Giang, Long An, and Can Tho was 4.75, 5.92, and 20.58 %, respectively. This suggests that amylose content not only depended on the rice variety but was also affected by cultivation and nutrition conditions. High temperatures during the granulation stage had different effects on different varieties [47,48]. An increase in nitrogen through fertilizer led to a decrease in amylose content [49]. Light during the granulation process if too much or too little will affect the amylose content [50,51]. Rice with insufficient light during the granulation stage will lead to reduced activity of amylose (granule-bound starch synthase) enzyme, thereby reducing amylose content.

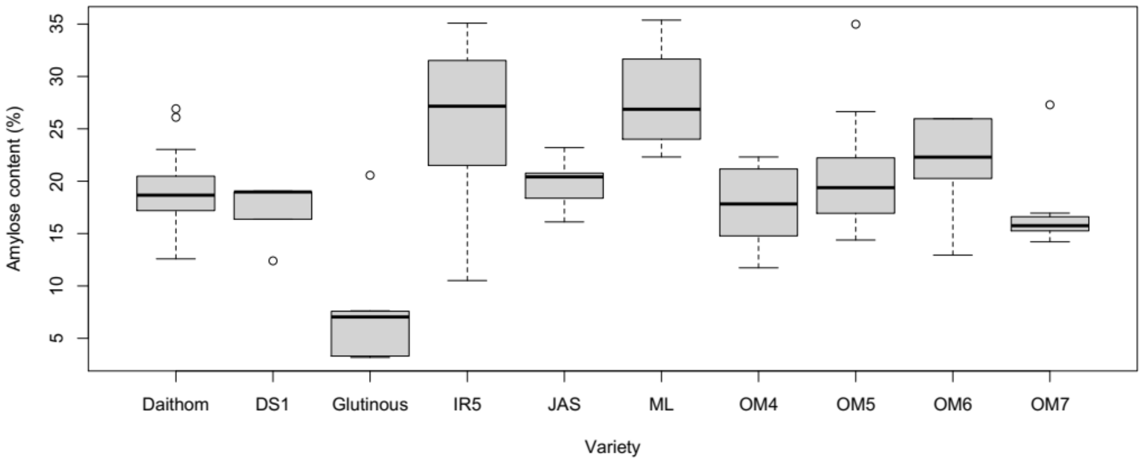

Figure 7. Amylose content by varieties.

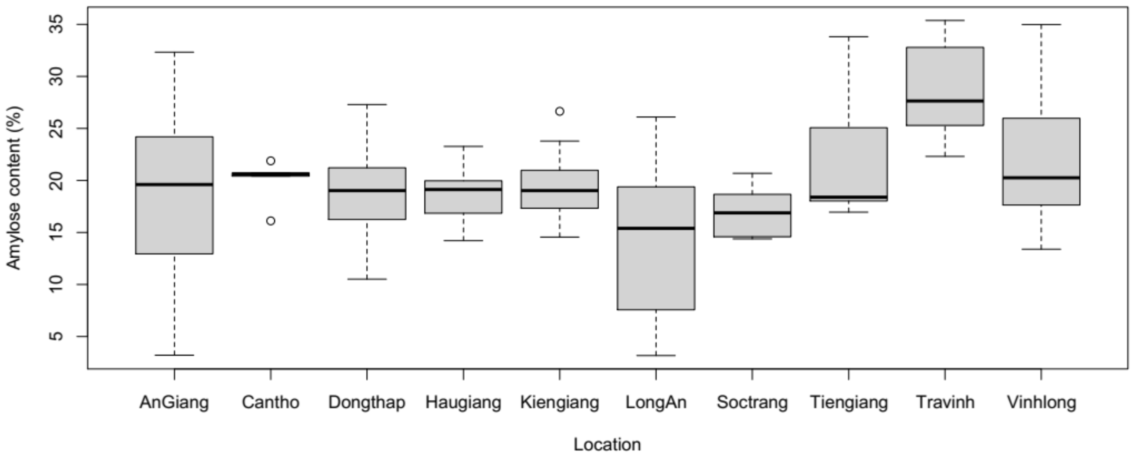

Figure 8. Amylose content by locations.

Starch content. The starch contents of 125 rice grain samples from the Mekong Delta region of Viet Nam are presented in Figure 9, which ranged from 76.47 to 91.22 %. The average starch content of the rice varieties in this study was almost higher than that of the rice samples from the Italian supermarket (75 - 77 %), and the aromatic rice varieties in Bangladesh (63 - 70 %) [33, 52]. In general, there was no difference in starch content between the varieties.

However, Figure 10 shows that there was a difference between the samples grown in different provinces with significant levels of 5 %. With Daithom variety, there was a difference between the samples from Dong Thap and those from An Giang, Kien Giang, Long An, and Soc Trang with the starch content fluctuating in the range of 63 - 82 % and 83 - 88 %, respectively. The average starch content in Hau Giang, Kien Giang, Soc Trang, Tra Vinh, and Vinh Long provinces was higher than in the other provinces, with values ranging from 83 to 85 % and 75 to 80 %, respectively. This variation could be attributed to fertilizer application, growing conditions, time and location of growing areas [53].

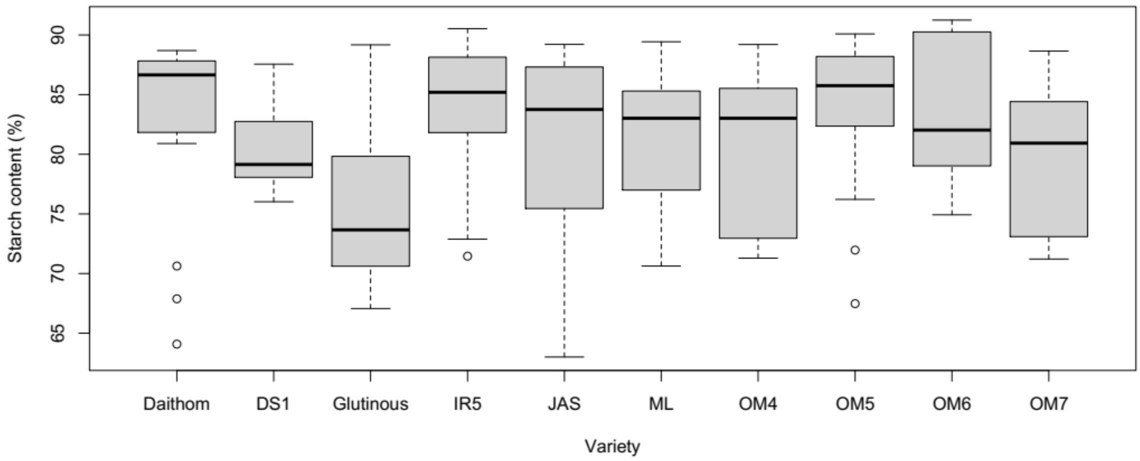

Figure 9. Starch content by varieties.

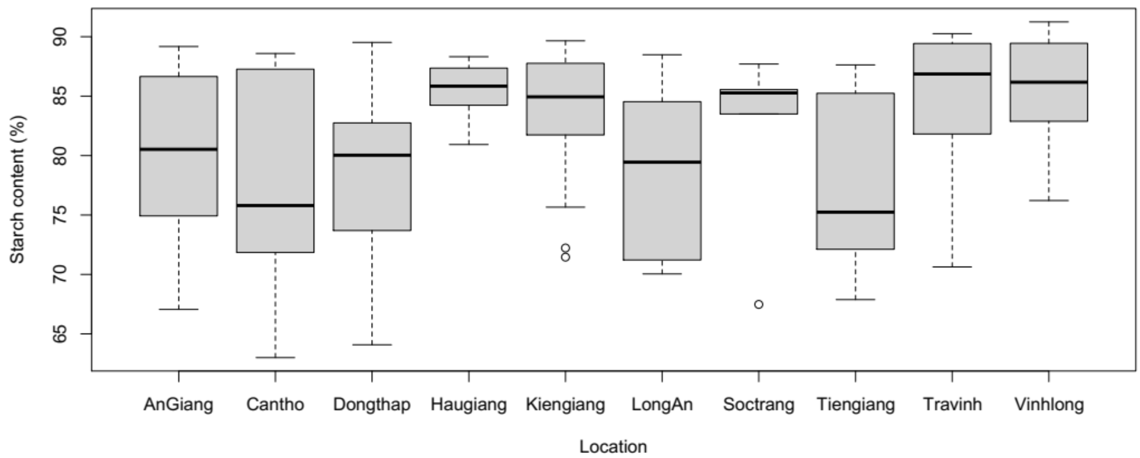

Figure 10. Starch content by locations.

Lipid content. Figures 11 and 12 show that the lipid content of rice grain samples from the Mekong Delta region of Viet Nam ranged from 0.19 to 2.27 %, but mainly concentrated in the range 0.25 - 1.1 %, of which ML variety had the highest lipid content (0.78 %). The lipid content of rice samples grown in the Mekong Delta was higher as compared to some Japanese cultivars (0.31 - 0.46 %, db.) [38]. In addition, the results in Figure 12 indicate that there was no difference in lipid content in rice samples between growing locations. Lipid content is the most susceptible property to being influenced by both environmental factors and farming conditions such as soil conditions (climate, soil, water, light, etc.), harvesting and storage conditions. Furthermore, Piggott *et al.* (1991) showed that the milling and polishing process of rice contributed to increased lipid content. If not thoroughly milled, the bran layer will adhere to the outside of the rice grain, increasing the lipid content by up to 20 % [54].

The reason for this difference was that the composition and content of rice lipid were mainly determined by genetics, however, this content was also influenced by environmental factors. Tong *et al*. (2014) suggested that the environment had a significant effect ($p < 0.05$) on the composition and phospholipids accumulation of rice, although the environmental impacts accounted for only 0.7 - 38.9 % of the total variance [55]. Goffman *et al*. (2003) showed that the environmental impacts significantly affected the total lipid content ($p < 0.05$), as well as the fatty acids C18:0, C18:1 and C18:3 ($p < 0.01$) [56]. Majumder *et al.* (1989) reported an increase in unsaturated rice lipids associated with low ambient temperatures [57]. Along with that, the post-harvest processes of rice such as milling and polishing process also significantly affect the composition and content of rice lipids in grain.

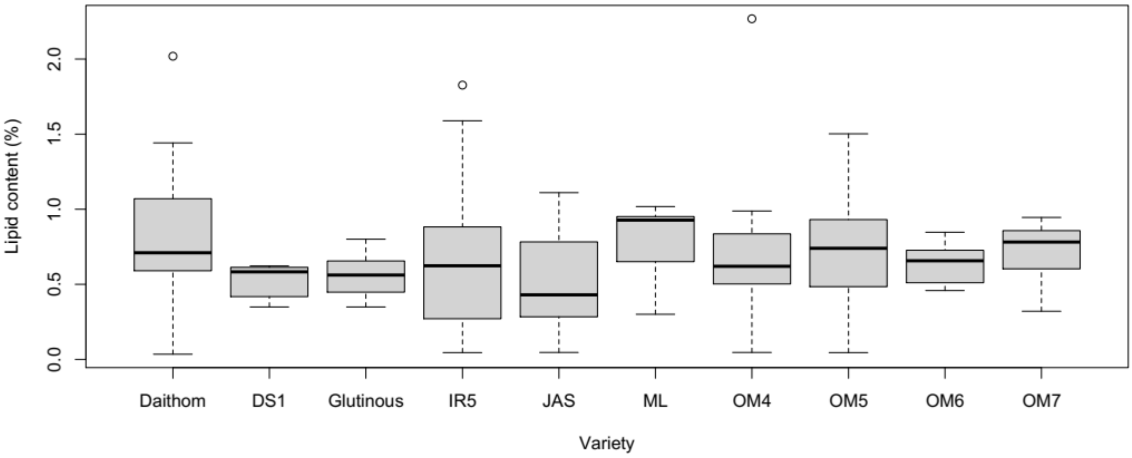

Figure 11. Lipid content by varieties.

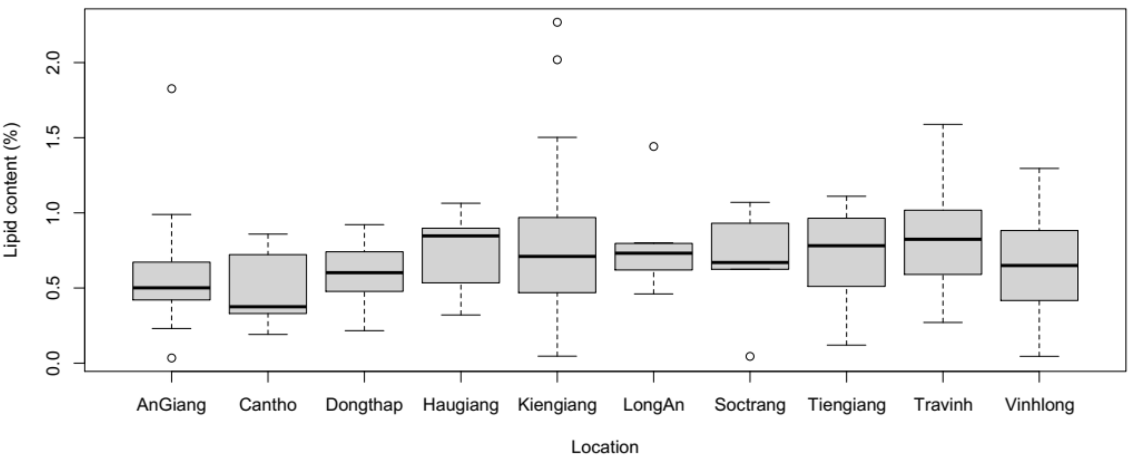

Figure 12. Lipid content by locations.

Correlation between properties

The principal component analysis was used to reveal the relationships between physicochemical properties by varieties. The relationships between physicochemical properties of samples by variety are shown in Figure 13. The first two principal components showed up to 67.5 % of the total variance (Dim 1 = 43.3 % and Dim 2 = 24.2 %). The varieties were divided into 3 groups with different characteristics. If the rice had a large dimension, the length was short and had a round grain shape, this was characteristic of glutinous and DS1 (Japanese rice). In addition to the same shape, both rice varieties had high amylopectin, and protein content. These were varieties with flexible adhesive properties [14, 37, 58]. If the rice had a high value in length, it was narrow in width and had a long slender shape such as OM rice varieties, JAS, and

Daithom. These rice varieties were also found to have higher moisture, lipid and ash content than other rice varieties. These properties are thought to be greatly influenced by the milling conditions and will have a negative impact on the quality of cooked rice. The majority of OM rice varieties are hybrid rice with good quality, good resistance to natural conditions, and good yield [59]. For hard rice varieties such as IR5, and ML, the results indicated that these samples had higher starch and amylose content than other varieties. The amylose content of hard rice varieties was found to be higher than other rice varieties, ranging from 17.63 to 35.09 %. It was a reason that resulted in a harder and less sticky texture of cooked rice.

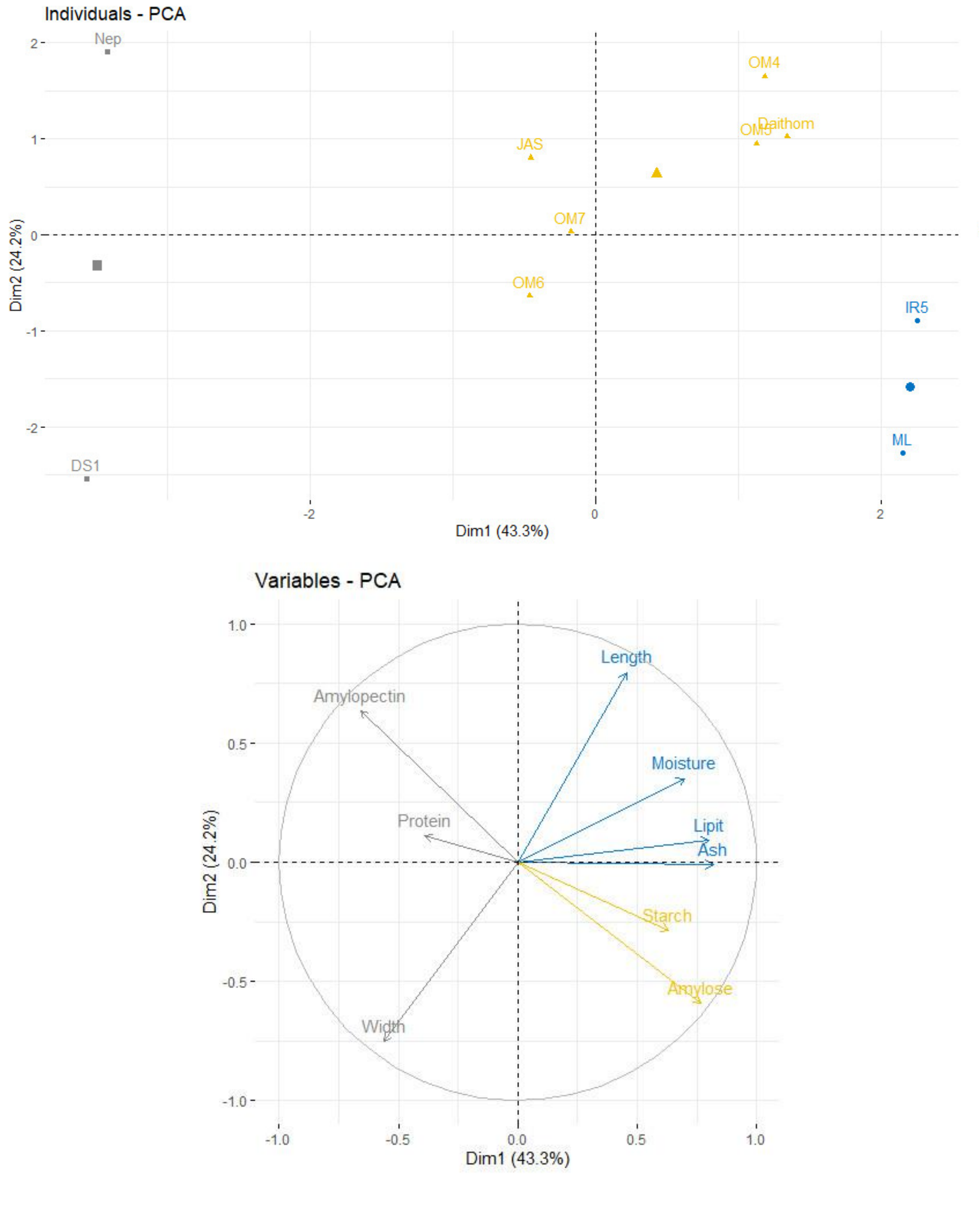

Figure 13. Multivariate analysis by variety.

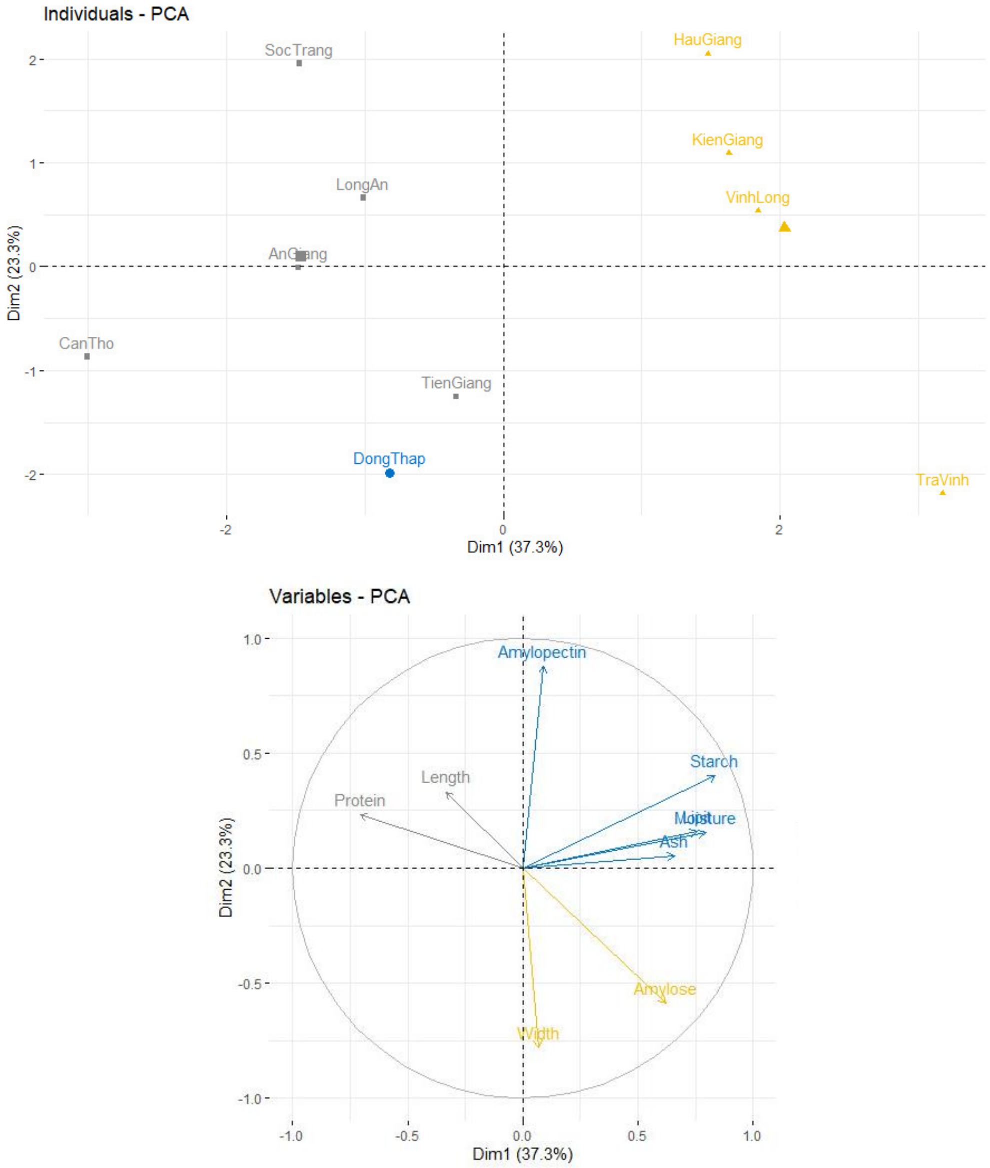

Figure 14. Multivariate analysis by location.

4. CONCLUSIONS

The results of physical analysis showed that 125 rice samples grown in the Mekong Delta did not have any difference in color. The rice grains were from medium to long in length and mostly slender in shape, with the exception of DS1, a *Japonica* variety that was round in shape. Chemical parameters were not much different from each other but there were clear differences in amylose content. A total of 125 samples were classified into three groups based on their physical and chemical properties. Length, moisture, lipid, and ash content were determined for group 1 samples which included hard rice varieties; particle shape, starch and amylose content were all characteristic of group 2 samples (IR5 and ML); finally, group 3 was distinguished by particle size, particle shape, protein and amylopectin content, which contained varieties of glutinous and DS1. Considering the amylose content, the rice varieties were divided into 4 groups in which 3 % of samples with very low amylose content (from 3 % to 9 %) were glutinous rice samples; 29 % of the medium range (from 20 % to 25 %) were mainly from varieties Jasmine85 and OM5451; 20 % belonged to the category of high amylose content (25 %) of varieties IR50404, ML202, and OM6976; 48 % of samples with low amylose content (from 9 % to 20 %) were from the remaining varieties. 125 samples were divided into three groups, group 1 was distinguished by protein content and length properties, and included samples from Soc Trang, Long An, An Giang, Can Tho, and Tien Giang. Group 2 only included samples from Dong Thap, whose mean grain width was greater than that of the other provinces, because there were many samples of DS1 (*Japonica* variety). Group 3, including the remaining provinces, was characterized by high content of starch, amylopectin, moisture, and ash, with the exception of Tra Vinh where the highest average amylose content (IR50404, and ML202) was recorded. The results also showed that there were differences between samples of the same variety grown in different areas, but these differences did not apply to all rice varieties.

Acknowledgements. We acknowledge the support of time and facilities from Ho Chi Minh City University of Technology (HCMUT), VNUHCM for this study

Credit authorship contribution statement. Ngo Thanh An: Methodology, Writing–original draft. Lai Quoc Dat: Formal analysis, Validation. Nguyen Quang Long: Formal analysis, Data curation. Nguyen Hoang Dung: Supervision, Writing–review editing. Pham Duy Tien: Conceptualization, Supervision.

Declaration of competing interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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