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Quality Variations of Khao Dawk Mali 105 (KDML 105) Rice in the Tung Kula Rong Hai Region of Thailand

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Abstract-The quality variations of Khao Dawk Mali 105 (KDML 105) rice produced from three different locations in Tung Kula Rong Hai, the biggest area producing KDML 105 in Thailand, were investigated. The grain qualities of this rice were evaluated for chemical, physical and morphological properties. A scanning electron microscope (SEM) was used to study the shape and surface details of rice starches. In general, grain size and cooking properties were not significantly different ($p>0.05$) among the three locations. On the other hand, there were some differences in chemical, texture and pasting properties. The results showed that the 2 - acetyl - 1 - pyrroline (2 - AP) content of the rice from one area (5.47 ppm) was significantly higher than those of the two other areas. Pasting temperature, cohesiveness and gumminess were slightly different ($p<0.05$) in the rice samples. Starch granule size at the outer and center layers of the endosperm of milled rice grain was also found to be significantly different at different growth sites. Capillary electrophoretic patterns of prolamin were found to be identical among analyzed samples. This study has added valuable information about the effects of growth conditions on qualities of Thai rice.

Keywords: 2 - acetyl - 1 - pyrroline (2 - AP), capillary electrophoresis (CE), starch microstructure, milled rice characteristics

1. Introduction

Khao Dawk Mali 105 (KDML 105), is commonly known as Hom Mali rice (in Thai), has been the most popular fragrant rice variety in Thailand since 1959 (Toojinda *et al.*, 2004). In 2010, Hom Mali rice was exported to 167 countries around the world, including the USA (22%), Hong Kong (11%), China (8%) and Ivory Coast (7%) (Esaan Center for Business, Faculty of

Management Science, Khon Kaen University (2011). KDML 105 is a drought tolerant variety of the highest quality and thus one of the most promising economic crops in the northeast of Thailand. Although this variety can be grown in all areas of

Thailand it is mainly found in the northeastern part. The important attribute of KDML 105 is its fragrance and softness. The aromatic substance 2 - acetyl - 1 - pyrroline (2 - AP) in KDML 105 grain enhances the aromatic quality. The 2 - AP content of the rice strain from northeastern Thailand, especially in irrigated areas of Tung Kula Rong Hai (Yoshihashi *et al.*, 2004), is higher than that from other regions. This region, regarded as one of the best growing areas for this rice, is a vast open area located in five provinces in the center of Northeast Thailand and covering about 336,000 hectares of land (Katawatin *et al.*, 1998). Since this region is very large, there are different ecological conditions and cultivation methods, particularly with regard to irrigation and fertilizers (Yoshihashi *et al.*, 2004). Additionally, the rice production, in general, depends on the amount of rainfall. The qualities of this rice in the region therefore varies greatly (Seanrungmueang, 2009).

The Thai government has promoted the production of KDML 105 in the Tung Kula Rong Hai region for mass trade since 1970. This has increased the rice production, thus providing more income for local communities as well as export markets (Seanrungmueang, 2009). Despite this government promotion, the variation of grain quality has not yet been widely studied. Therefore, quality evaluation in grain of the KDML 105 variety grown in this region was of interest. The objective of this study was mainly to investigate the 2 - acetyl - 1 - pyrroline (2 - AP) content, protein content, physical properties, milled rice characteristics and starch characteristics of KDML 105 samples grown at different locations in Tung Kula Rong Hai. Capillary electrophoresis (CE) was also used for evaluation of prolamin profiles as affected by growth conditions. It is expected to provide this information for a database of Thai rice quality.

2. Materials and Methods

2.1 Materials

The samples of Hom Mali paddy rice were obtained from three different growth locations in the Tung Kula Rong Hai region, Northeast of Thailand (three replicates for each site). The important characteristics of this land are described in (Table 1). The samples were cropped following conventional methods in the areas. Paddy - rice samples (KDML 105) were taken to determine physical properties and some paddy rice was milled to separate husk from the brown rice as contents of moisture, protein, 2 - AP as well as physical properties were examined. Then this brown rice was polished to obtain milled rice. Milled whole rice kernels were separated from the broken rice to analyze for CE, milled rice characteristics (physical, cooking and textural properties) and starch characteristics (scanning electron microscopy (SEM), amylose content and pasting properties). To obtain flour and milled rice samples (KDML 105) from different growth locations, the samples were ground and passed through a 100 - mesh sieve screen.

Table 1. Important land and soil characteristics, yield and total rainfall of three experimental locations

Growth Location	TL1	TL2	TL3
Yield (t/ha)*	3.33	4.36	4.41
Total rainfall (mm)*	1,153	1,455	1,325
Soil Fertility**	Quite Low	Low	Low
pH**	<5.5 - 6.5	5.6 - 6.5	5.6 - 6.5
Suitability of soil**	Moderate	High	Moderate
Texture of soil**	Sand	Clay	Clay
Salinity**	Zero	Zero	Zero

Source: * (Aung, 2006), ** (Udomsri *et al.*, 2003)

2.2 Moisture Content

Moisture content was determined using the AACC Method 44 - 15A (AAAC., 2000c) In brief, three - gram portions of brown rice flour from each location were transferred into separate moisture dishes prior to heating in an oven for exactly 16 hrs. at 130ºC (±1ºC).

2.3 2 - acetyl - 1 - pyrroline (2 - AP)

The 2 - AP content was determined using a modified method of Wongpornchai *et al.* (2004). Solvent extraction was carried out on the brown rice flour. Five grams of the ground rice powder was used to carry out three replications of each sample. The samples were then placed into 125 - ml flasks containing 50 ml of 0.25 mg/l 2,4,6 - trimethylpyridine internal standard solution (dissolved in 0.1 M HCL), vortexed for 30 min at room temperature and centrifuged for 5 min at 5,000 rpm at 4ºC and the supernatant was collected. The supernatant was then transferred to a 125 - ml pear-shaped separatory funnel. Approximately 1.2 ml of 5.0 M NaOH was then added to make the solution slightly basic. Fifty milliliters of dichloromethane was immediately added as an organic solvent. The extraction was carried out twice and the combined dichloromethane portions were collected. Following drying with anhydrous sodium sulfate, this extract was concentrated to 1 ml by removing dichloromethane using a rotary evaporator under reduced pressure at a temperature of 28ºC. The resulting concentrated extract was transferred to a vial and left open to air at room temperature until its volume decreased to 0.1 ml. This sample was subjected to a quantitative analysis by capillary GC (GC - 17A, Shimadzu, Japan) with a flame ionization detector (FID). The entire experimental process was repeated for the extraction and analysis of standard 2 - AP of known amounts in a dilution series in order to obtain a standard calibration curve. A fused silica capillary column HP - 5, biphenyldimethylpolysiloxane, measuring 30 mm × 0.25 mm internal diameter and 0.25 µm film thickness (Agilent Technologies) was programmed, starting at 50ºC. The temperature was increased to 120ºC at a rate of 5ºC/min resulting in an overall separation time of 30 min with 10 µl injection volume. The injector temperature was set at 250ºC and was operated in a split mode with a split ratio of 20:1. Purified helium was used as the GC carrier gas at a flow rate of 1 ml /min.

2.4 Protein Analysis

Protein content was determined using the Kjeldahl Method (AOAC.,1996). The proteins of rice starch were fractionated by CE. CE of KDML 105 extracts, modified from a method of Siriamornpun *et al.* (2004), was used to identify rice varieties. The method provided good separations of the rice proteins. For prolamin protein extraction, 1 g of milled rice flour (ground using a mortar) was used to carry out three replications of each sample. The samples were then placed into 1.6 - ml eppendorf tubes. After that, 1 ml of 50% 1 - propanol was added and these mixtures were vortexed for 1 min and left for 5 min at room temperature and then centrifuged for 2 min at 14,000 rpm. This process was then repeated. The resulting two supernatants were collected and filtered through 0.45 µm filters. Fractionation was performed on a Beckman P/ACE MDQ32 (Beckman Instruments, Inc., Palo Alto, CA) with Karat Software configured on an IBM personal computer, using uncoated fused silica capillaries (50 µm i.d., 24 cm). Electrophoresis was conducted at 40ºC at a voltage of 10 kV using a UV detector at 200 nm. Samples were injected hydrodynamically at 5 psi. The capillaries were rinsed sequentially between successive electrophoretic runs with 0.1 mol/L sodium hydroxide (2 min), deionized water (2 min), and 50 mol/L IDA buffer, pH 2.5 (1 min). Separations were conducted using iminodiacetic acid (pH 2.5) containing 0.05% hydroxy propylmethylcellulose (HPMC) and 20% acetonitrile.

2.5 Milled Rice Characteristics

Physical properties

One thousand kernels of milled, brown or paddy rice were counted randomly in triplicate and weighed separately. The length (L), width (W) and thickness (T) as well as length - width ratio (L/W) of 50 rice grains were determined (Gujral and Kumar, 2003).

Cooking properties

Minimum cooking time, water uptake ratio, elongation ratio and solid loss were determined according to the method of Singh *et al.* (2005). Two - gram head - rice samples were transferred into a test tube and 20 ml of distilled water were added. This mixture was then put into a boiling water bath. Sample preparation was followed these steps for all cooking properties.

Minimum cooking time: After boiling for 10 min in a water bath, three rice kernels were removed every minute during the cooking process. They were then pressed between two microscope glass slides. The appearance of a white core indicated an uncooked sample. The time (minutes) at which the rice showed no white core was reported as a minimum cooking time.

Water uptake ratio: Rice samples were cooked for a minimum time, drained and the excess water was removed by pressing the samples between filter paper sheets. These samples were then accurately weighed and the water uptake ratio was calculated.

Elongation ratio: A cumulative length of 10 cooked rice kernels divided by average length of 10 raw kernels was reported as an elongation ratio.

Solid loss: The samples were cooked for the minimum cooking time, the gruel was then transferred to a 50 ml beaker, and the rice was washed several times with distilled water, and the water drained into the gruel beaker. The gruel beaker was then topped up with no more than 20 ml of distilled water. The aliquot with leached solids was evaporated in an oven at 110 °C until completely dry. The solids were weighed and their percentage was noted.

Textural properties

Cooked milled rice samples were prepared for the minimum cooking time. Texture profile analysis (TPA) was then performed using a TA - XT2® texture analyzer (Stable Micro System Ltd., UK) equipped with the Texture Expert Exceed® software version 1.22 and 25 kg load cell. A 50 mm diameter aluminum cylinder probe and aluminum base was used. The instrument was run in a compression mode to measure force with texture profile analysis (TPA) option. This option was used to operate the machine for two cycles (bites) of compression test with 5 seconds delay time. In every run, the base and probe were cleaned with 70% ethanol and allowed to dry. Before starting the test run, the probe was positioned manually on the top surface of the grains. The running deformation was set to 75% strain with a testing speed of 1.0 mm/s. Three grains of cooked milled rice were randomly selected and laid on the base. A total of 12 replicates were tested for the properties. Force - time and force - deformation curves were obtained from the test as the following textural parameters were calculated: hardness (N), stickiness (N), adhesiveness (NS - 1), cohesiveness (unit less), gumminess (N), springiness (unit less) and chewiness (N) (Amornsin, and Siriamornpun, 2004).

2.6 Starch Characteristics

Scanning Electron Microscopy (SEM)

The microstructures of KDML 105 translucent rice kernels were observed using an SEM (JSM - 6460LV; JEOL, JAPAN) at 10 kV. The rice kernel was split along the cross - sectional axis using a cutter blade. A location at about 0 - 0.3 mm from the lateral surface of both grain width and grain thickness was designated as outer - layer endosperm. A location at about 0.3 - 0.7 mm from the inner boundary of the outer layer endosperm of both grain width and grain thickness was designated as inner - layer endosperm. The remainder was designated as the center - layer endosperm. Samples were attached to an SEM stub using double - backed cellophane tape. The stub and sample were coated with gold - palladium and examined. The cellular structure and starch granules were photographed and the starch - granule size was measured.

Amylose content

The amylose content was determined using AACC method 61 - 03 (AACC., 2000a). This method determined the apparent amylose content of milled rice by colorimetric determination at 620 nm of the greenish - blue starch - iodine complex developed at pH 4.5 - 4.8 in acetate buffer.

Pasting properties

Pasting characteristics were determined using AACC method 61 - 02 (AAAC., 2000b) Head rice kernels were ground and passed through a 100 - mesh sieve screen to obtain milled rice flour. Three grams of milled rice flour were weighed and transferred into each test canister. After that, 25 ml of distilled water was added. The pasting properties of the milled rice were then determined using a Rapid Visco Analyser (RVA) (RVA - 4; Newport Scientific Instrument and Engineering, Australia) in terms of pasting temperature (temperature of the initial viscosity increase), breakdown (the difference between peak viscosity and trough), final viscosity (viscosity achieved at the end of the test) and setback (the difference between final and peak viscosity).

2.7 Statistical Analysis

The results were analyzed using analysis of variance (ANOVA) and reported as mean ± SD. Duncan's new multiple range test was used to determine significant differences. Statistical significance was declared at $p<0.05$.

3. Results and Discussion

3.1 Moisture, Protein and 2 - AP Contents

A Paddy rice samples harvested from three different growth sites located in Tung Kula Rong Hai, namely TL1, TL2 and TL3, were selected for our experiment. The paddy samples were evaluated for their physical qualities. Brown rice was studied for chemical properties and milled rice was analyzed for cooking, pasting and microstructure properties. Furthermore, the prolamin protein of rice collected from different growth sites was evaluated using CE. The results of this study were as follows:

Table 2. Moisture, protein and the 2 - AP contents of KDML rice grains from different growth locations

Rice sample	Moisture content^{ns} (% db)	Protein content (%db)	2 - Acetyl - 1 - Pyrroline (ppm)
HM - TL1	11.47±0.39	6.92±0.09^{b}	5.47±0.19^{a}
HM - TL2	11.69±0.40	7.18±0.08^{a}	5.10±0.10^{b}
HM - TL3	11.85±0.33	7.14±0.06^{a}	5.00±0.19^{b}

$^{(a-b)}$ Significant differences between means for a given within the same column ($p<0.05$).
^{ns} No significant differences between means for a given within the same column ($p>0.05$).

HM = Hom Mali rice, TL1 - 3 = Locations 1 - 3 in Tung Kula Rong Hai region, L1 = Phayakkhaphum Phisai district in Maha Sarakham province, L2 and 3 = Kaset Wisai and Phon Sai districts, respectively, in Roi - Et province

Moisture, protein and 2 - AP content of KDML 105 rice grown at different locations are shown in (Table 2). Moisture content of the samples were in a range of 11.47 - 11.85 (% db) and were not significantly different. These values were lower than those reported for Thai Hom Mali Rice Standard 2001 (Cheaupun, *et al.*, 2005). This was possibly due to an overly dry rice paddy, resulting in a weight loss in the rice grains. The protein and 2 - AP contents were significantly different ($p<0.05$) in different growth locations. The protein content of HM - TL2 and HM - TL3 was higher than that of HM - TL1 and they were in the range of 6.92–7.14 (% db). Protein content in HM - TL1 was the lowest among three samples. This possibly related to a lower use of fertilizer and the sandy texture of the field (Table 1). The 2 - AP content of HM - TL1 was higher than that of HM - TL2 and HM - TL3 (Table 2). The values (5.00 - 5.47 ppm) are higher than those previously reported, namely, 0.3 - 0.6 ppm (Yoshihashi *et al.*, 2004) and 0 - 0.61 ppm (Kong - ngern *et al.*, 2011) in brown rice harvested from Tung Kula Rong Hai. These high values of 2 - AP in HM - TL1 rice grain were likely due to the dry and sandy conditions of the fields (Table 1), as reported in Yoshihashi *et al.* (2004) and Kong - ngern *et al.* (2011). Furthermore, the stress of drought during the milky stage of ripening can lead to an increase in 2 - AP (Yoshihashi *et al.*, 2004). Gay *et al.* (2010) have reported soil salinity to be positively associated with the content of 2 - AP, a key volatile compound of rice aroma. However, the soils used in this experiment had zero salinity (Table 1).

3.2 Capillary Electrophoretic Patterns of Rice Prolamin

CE profiles of rice prolamin extracted from milled rice endosperm are shown in Figure 1 The results showed that patterns of prolamin protein were identical in all three samples collected from different growth locations. However, protein contents were different, as can be seen from the peak heights (absorbance). The profile similarities are in agreement with previous studies by Siriamornpun *et al.* (2004) and MacRitchie and Gupta (1993). Prolamin proteins of the same variety of cereal are not affected by environment or growth locations, whereas protein content may vary depending on climate or farm management. This present study has demonstrated that, despite growth - related variations in other qualities of rice (chemical and textural properties), protein finger prints still remain identical for the same variety.

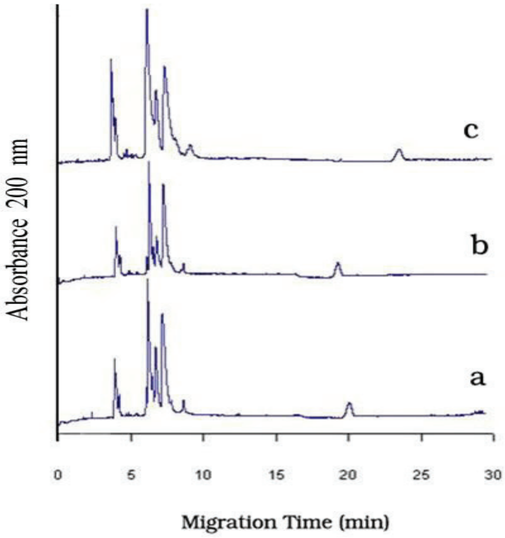

Figure 1. CE profiles of prolamin from KDML 105 milled rice flour samples at three different growth locations: HM - TL1 (a), HM - TL2 (b) and HM - TL3 (c).

5.3 Milled rice characteristics

Physical properties

The 1000 - kernel weight, length, width, thickness and L/W ratio (Table 3) were determined in the following order for all samples; paddy, brown and milled rice. The data showed no significant difference except for the width of paddy rice. HM - TL3 had the highest width value, and HM - TL2 showed the lowest. The widths of brown and milled rice were not significantly different. The width of paddy rice varied from 2.40 mm to 2.47 mm, brown rice from 2.12 mm to 2.17 mm and milled rice from 2.03 mm to 2.07 mm. The thickness of paddy, brown and milled rice for all of three locations was not significantly different ($p>0.05$). However, the length - width (L/W) ratio of the paddy rice was significantly different with the L/W ratio of the HM - TL2 was higher than that of HM - TL1 and HM - TL3. The L/W ratio of brown and milled rice was not significantly different. Based on the results of Adu - Kwarteng *et al* (2003), the shape of milled rice (KDML 105) from the three locations was long and slender. The length and L/W ratio of milled rice were higher than Thai Hom Mali Rice Standard B.E. 2544 (Cheaupun, *et al.*, 2005). In international markets, a significant difference in milling quality characteristics and shape profiles reflect an importance of export demand. The preferences of consumers in several countries for good quality and fragrance of rice are similar, but preferences for shape and chemical attributes seem to vary (Unnevehr, 1986).

Cooking properties

There were no significant differences in minimum cooking time, water uptake ratio, elongation ratio and solid loss for milled KDML 105 rice grown at the different locations (data not shown). This may be due to similarities in cellular structures and starch granule sizes for grains from each location. Lisle *et al.* (2000) have reported that a compact structure has a slower water uptake, resulting in a longer cooking time. Chakrabarthy *et al.* (1972) reported that cooking time positively correlated with protein content. More protein forms a thicker barrier around the starch granules, thus slowing water uptake by each granule. The solid loss of cooked rice in HM - TL2 and HM - TL3 was higher than that in HM - TL1 but they were not significantly different. This may be due to similarities in the amylose contents. Singh *et al.* (2005) reported that amylose and protein contents affected solid loss. The elongation ratios of KDML 105 in the three locations were very close. Ong and Blanshard (1995) reported that differing elongation ratio may be due to differences in amylose content and granular structure.

In Thailand, the mill owner mostly uses minimum cooking time to determine the mixture of aromatic rice with other varieties that have a similar grain appearance. Different rice varieties have different minimum cooking times (Singh *et al.*, 2003), so this is a simple, low cost method of ascertaining the mix of the rice.

Table 3. Physical properties of KDML 105 rice grains from different growth locations

Rice sample	Location	1000 - kernel weight (g)	Length (mm)	Width (mm)	Thickness (mm)	L/W ratio
Paddy rice	TL1	27.23±0.76[a]	10.54±0.19[a]	2.42±0.03[ab]	2.00±0.04[a]	4.36±0.09[b]
	TL2	27.68±1.62[a]	10.54±0.13[a]	2.40±0.05[b]	1.97±0.01[a]	4.39±0.06[a]
	TL3	27.51±0.08[a]	10.63±0.14[a]	2.47±0.04[a]	1.97±0.02[a]	4.31±0.09[b]
Brown rice	TL1	21.70±0.12[b]	7.32±0.06[b]	2.17±0.03[c]	1.74±0.02[b]	3.38±0.06[c]
	TL2	22.18±0.49[b]	7.33±0.04[b]	2.12±0.02[cd]	1.74±0.02[bc]	3.46±0.02[c]
	TL3	22.37±0.43[b]	7.36±0.04[b]	2.13±0.03[c]	1.73±0.03[bcd]	3.46±0.03[c]
Milled rice	TL1	19.68±0.22[c]	7.27±0.07[b]	2.07±0.01[de]	1.70±0.03[cd]	3.51±0.02[c]
	TL2	20.20±0.78[c]	7.32±0.06[b]	2.03±0.04[e]	1.69±0.01[d]	3.60±0.06[c]
	TL3	19.99±0.03[c]	7.31±0.08[b]	2.06±0.02[e]	1.73±0.04[bcd]	3.54±0.06[c]

[(a - e)] Significant differences between means for a given within the same column (p<0.05).

Textural properties

The textural properties of cooked rice (KDML 105) grown at different locations are shown in (Table 4). The cohesiveness and gumminess were significantly different (p<0.05). The cohesiveness and gumminess of milled rice cooked from HM - TL2 and HM - TL3 were significantly higher than that in HM - TL1. However, hardness, stickiness, adhesiveness, springiness and chewiness were not significantly different. Singh *et al.* (2005) have reported that textural parameters showed a very strong positive correlation with amylose content and water uptake. Higher value for hardness in both HM - TL2 and HM - TL3 could possibly be attributed to differences in their granular structure. A significant positive correlation of gruel solid loss was found with cohesiveness and hardness. A higher hardness has been reported in rice cultivars with small starch granules (Singh *et al.*, 2003).

3.4 Starch characteristics

Scanning Electron Microscopy (SEM)

The cellular structure and starch granule morphology of milled KDML 105 rice kernels from different locations are shown in Figure 2 and the starch granule sizes are shown in (Table 4). The cells and amyloplasts were observed as irregular in shape and packed tightly within the translucent grains. The starch granule sizes at the outer layer endosperm and center layer endosperm were significantly different ($p<0.05$) whereas the starch granule size at the inner layer endosperm showed no significant difference. In addition, the starch granule size of the center layer endosperm was smaller than that of the outer layer endosperm. The starch granule size at the outer layer endosperm of HM - TL1 was the largest, while the HM - TL3 showed the smallest size (3.96 - 4.16 µm). However, the starch granules at the center layer endosperm of HM - TL3 seemed to be larger than the others. The starch granules at inner layer endosperm were in the range of 3.23 - 3.94 µm.

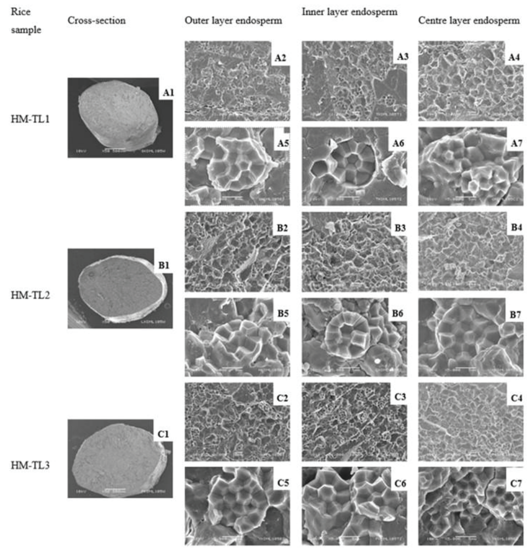

Figure 2. Scanning electron micrograms of KDML 105 translucent grain from different locations in the Tung Kula Rong Hai region, Northeast of Thailand. Shape and surface details of HM - TL1 are Cross - section (A1, ×50), cellular structures of outer (A2), inner (A3) and center (A4) layer endosperm (×1,000) and starch granule structures of outer (A5), inner (A6) and center (A7) layer endosperm (× 5,000). Shape and surface details of HM - TL2 are Cross - section (B1, ×50), cellular structures of outer (B2), inner (B3) and center (B4) layer endosperm (×1,000) and starch granule structures of outer (B5), inner (B6) and center (B7) layer endosperm (× 5,000). Shape and surface details of HM - TL3 are Cross - section (C1, ×50), cellular structures of outer (C2), inner (C3) and center (C4) layer endosperm (×1,000) and starch granule structures of outer (C5), inner (C6) and center (C7) layer endosperm (× 5,000).

Table 4. The characteristics of KDML 105 rice grains from different growth locations

Textural properties of cooked rice of KDML 105 from different growth locations.			
Rice sample	HM - TL1	HM - TL2	HM - TL3
Hardness^{ns} (N)	10.96±1.80	11.35±1.40	11.69±1.36
Stickiness^{ns} (N)	- 1.60±0.56	- 1.45±0.36	- 1.54±0.44
Adhesiveness^{ns} (NS^{-1})	- 0.49±0.23	- 0.56±0.16	- 0.60±0.25
Cohesiveness (Unitless)	0.23±0.03^{b}	0.25±0.02^{a}	0.25±0.02^{a}
Gumminess (N)	2.56±0.54^{b}	2.80±0.41^{a}	2.92±0.44^{a}
Springiness^{ns} (Unitless)	0.56±0.59	0.46±0.12	0.52±0.12
Chewiness^{ns} (N)	1.13±0.28	1.29±0.38	1.50±0.45
Starch granule size of translucent kernel rice at three areas of KDML 105 from different growth locations evaluated using SEM.			
Outer layer endosperm (µm)	3.46 - 4.81 (4.16)^{a}	3.26 - 4.77 (4.04)^{ab}	3.18 - 4.93 (3.96)^{b}
Inner layer endosperm^{ns} (µm)	3.33 - 4.68 (3.94)	2.65 - 4.16 (3.23)	2.66 - 4.25 (3.36)

Table 4. The characteristics of KDML 105 rice grains from different growth locations (cont.)

Textural properties of cooked rice of KDML 105 from different growth locations.			
Centre layer endosperm (µm)	2.05 - 3.83 (3.07)^{b}	3.09 - 4.98 (3.99)^{ab}	3.17 - 4.87 (4.07)^{a}
Amylose content and pasting properties of milled rice powder of KDML 105 from different growth locations.			
Amylose content^{ns} (% db)	19.32±0.22	19.74±0.34	19.43±0.49
Pasting temperature (ºC)	73.50±0.42^{a}	73.60±0.40^{a}	72.69±0.18^{b}
Breakdown^{ns} (RVU)	82.71±2.90	80.07±2.46	82.69±5.53
Setback^{ns} (RVU)	77.24±2.50	77.27±3.15	76.60±6.20
Final Viscosity^{ns} (RVU)	183.11±8.00	194.57±7.86	197.00±9.39

$^{(a-b)}$ Significant differences between means for a given within the same row (p<0.05).
^{ns} No significant differences between means for a given within the same row (p>0.05).

Amylose content and pasting properties

Amylose content and pasting characteristics are shown in (Table 4). The amylose content of the samples was not significantly different (19.32 - 19.74, % db). Amylose content is the most important chemical characteristic determining the hardness of cooked rice (Unnevehr, 1986). Hom Mali rice variety is a low - amylose type (less than 20% amylose) and always has a soft, sticky texture when cooked (Cheaupun, *et al.*, 2005). The amylose content and aroma have been reported to be positively correlated with the purchase price (Unnevehr, 1986). Pasting properties evaluated in this study include pasting temperature, breakdown, setback and final viscosity. The pasting temperature was significantly different but breakdown, setback and final viscosity showed no significant difference among the rice samples from the three locations. The pasting temperatures of HM - TL1 and HM - TL2 were higher than that of HM - TL3. The variation in pasting properties of Hom Mali rice flour may be due to amylose and lipid content and to the branch chain - length distribution of amylopectin. Amylopectin contributes to the swelling and pasting properties of starch granules, while amylose and lipids inhibit the swelling (Tester and Morrison, 1990). Also, the amylopectin chain - length and amylose molecular size produce synergistic effects on the viscosity of starch pastes (Jane and Chen, 1992). From this result, HM - TL2 had higher amylose content, pasting temperature and setback than the rice harvested from other locations. This may show that these factors are associated. Noda *et al.* (2003) have reported that setback positively correlates to amylose content for low amylose rice starches. The high setback of HM - TL2 may be due to the amount and the molecular weight of the amylose leached from the granules and the remnants of the gelatinized starch (Loh, 1992). Besides, the rice proteins play a significant role in pasting by possibly encasing the starch granules and regulating their swelling and resistance to shear at high temperatures (Likitwattanasade and Hongsprabhas, 2010).

According to the results obtained from our present study, we recommend that KDML 105 should be grown under conditions with low salt, low total rainfall, low fertilizer, drought and sandy soil (Kong - ngern *et al.*, 2011; Aung, 2006; Cha - um *et al.*, 2010; Udomsri *et al.*, 2003; Yoshihashi *et al.*, 2004). In addition, the handling of paddy grain is an important process. Great care must be taken to avoid damaging grain or losing fragrance during drying and storage.

4. Conclusion

The data from our present study show that the chemical, textural and pasting qualities of the KDML 105 variety vary in different growth sites in the Tung Kula Rong Hai region. The aromatic substance (2 - AP content), pasting temperature, cohesiveness and gumminess were significantly different ($p<0.05$). Whereas other attributes, particularly physical properties, were similar. The CE patterns of rice prolamins could be used for varietal identification of KDML 105 and not affected by growth locations. These attributes account for the grain qualities of KDML 105, which has become a premium rice product providing a high return to both the farmer and the country on the international market.

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