CHAPTER 5

EFFECTS OF NATURAL AGING ON PHYSICO-CHEMICAL PROPERTIES AND AROMA INTENSITY OF RICE CV. KDML 105

5.1 Introduction

Changes in physico-chemical properties of rice during storage have been studied extensively by a number of researchers (Villareal et al., 1976; Chrastil, 1990a; Chrastil and Zarins, 1992; Perdon et al., 1997 ; Sowbhagya and Bhattacharya, 2001; Zhou et al., 2003). Storage has been known to alter rice to become better in some cooking properties and these properties are related to consumer preference, for examples, more volume expansion or non pasty and fluffier after cooking. Storage causes change in functional properties and this change is required by manufacturers using rice as a raw product. Storage or another used word in this study is natural aging, can however change rice to have undesirable properties such as change rice color to be yellowish, and for the most important, it changes aroma quality of fragrant rice (Widjaja *et al*., 1996a; Wongpornchai *et al*., 2004; Yoshihashi *et al*., 2005).

This experiment was conducted to investigate changes in some physico-chemical properties such as color, kernel elongation, pasting and textural properties, and change in aroma quality in terms of the amount of 2-acetyl-1-pyrroline and the relative amount of *n*-hexanal of rice cv. KDML 105 that was naturally aged during storage in rough rice form in ambient condition. The information derived at 2-month intervals from the storage period of 12 months indicated degrees of rice aging and gave us a better understanding on the change in rice quality attributes of the most important Thai fragrant rice. This information was also used as references to compare with the results from the accelerated aging experiment as discussed in Chapter 4.

5.2 Materials and Methods

5.2.1 Sample Preparations and Analyses

KDML 105 rough rice was obtained from the same lot that was prepared for the experiment conducted in Chapter 4. The rough rice samples were sun-dried to approximately 14% MC and stored in jute sacks in ambient condition. Change due to natural storage was monitored at 2-month intervals for a storage period of 12 months.

For each time of measurement, paddy sample was dehulled by a McGill sample sheller and then milled the resultant brown rice for 30 sec in a friction-type miller operating with a 1.0 kg weight positioned at the end of a 25-cm mill lever arm. Head rice was separated from the broken kernel by a cylinder grader and was used as rice sample. Change due to storage was monitored on the basis of change in color, kernel elongation, pasting properties, textural properties, amount of 2-acetyl-1-pyrroline and the relative amount of *n*-hexanal. All the tests were done in similar procedures as discussed in Chapters 3 and 4.

5.2.2 Statistical Analysis

Physico-chemical properties and aroma data were analyzed using analysis of variance (ANOVA) to determine the effect of storage time. Duncan's multiple range test ($P<0.05$) was used to separate the means.

5.3 Results and Discussion

5.3.1 Pasting Property

Pasting properties of the naturally-aged rice samples were measured using RVA instrument and their pasting characteristics were studied through the resulting RVA curves. Sample preparations and RVA operations were done with high accuracy to minimize error between each data collection time. Table 5.1 shows all the viscosity parameter results and Figure 5.1 illustrates RVA performance of flour samples obtained from stored paddy. The results derived from this experiment were very helpful for investigating the effect of accelerated aging treatments on pasting properties discussed in Chapter 4.

In general, pasting curves of the naturally-aged rice samples were lifted up during the first few months of storage. This was due to the rapid increases in peak, trough and final viscosity (Figure 5.1). After storage for 4 or 6 months, peak viscosity, trough and final viscosity declined significantly. Increase followed by a decrease in these RVA parameters did not occur at the same time and incurred the changes with different magnitudes. These differences resulted in variation in the values of breakdown and setback. For pasting temperature, the RVA pasting data collected over 12 months showed a steady increasing trend. The pasting temperature significantly increased from 80.7°C at the beginning of the storage time to 86.5°C in the 12-month stored samples. This indicated the reduction in starch granule solubility and that the granule required higher temperature and/or longer time to initiate gelatinization process of flour from the longer storage rice samples. Changes in pasting property of this study was in agreement with various reports conducted earlier (Perdon et al., 1997 ; Sowbhagya and Bhattacharya, 2001; Zhou et al., 2003; Soponronnarit *et al*., 2008). In the previous studies, peak viscosity, trough and breakdown were observed to increase in a few months of storage. Increase in peak viscosity was attributed to the increase in rigidity of starch granule.

Activity of amylase was less in aged rice as had been reported by Dhaliwal et al. (1991) and was linked to the increase in RVA peak viscosity (Zhou et al., 2003). Changes which occurred at molecular level of rice starch granule components, including change in protein structure, had been reported to associate with changes in pasting properties of rice during storage (Martin and Fitzgerald, 2002; Fitzgerald, et al., 2003; Zhou et al., 2002, Zhou et al., 2003). Decrease of starch granule solubility has been attributed to change in the property of granule surface protein and this change could limit rate of water penetrating into the granule and could also limit its swelling (Zhou et al., 2003). From the results of this present study, changes in pasting behavior of naturally-aged rice samples could mainly be explained by the change in hydration property of the rice starch granule. These changes occurred continuously as the time passed. The reduction in their hydration was confirmed by the increase in pasting temperature and lower peak viscosity. Prolonging of storage time, the rigidity of the starch granules continued to increase and hence, the pasting curve became lower in the longer stored rice.

5.3.2 Textural Property

Texture profile analysis attributes of cooked rice prepared from freshly harvested and from stored rice over 12 months are presented in Table 5.2. Storage time affected textural property of stored rice samples by increasing hardness, springiness and decreasing adhesiveness. Hardness of cooked rice was reported to be

Table 5.1 RVA viscosity parameters of KDML 105 rice flour during storage as paddy for 12 months at ambient temperature.

Pasting properties (cP)	Storage time (months)						
	0	2	4	6	8	10	12
- pasting temperature (^{o}C)	80.7±0.4^{d}	83.0±0.4^{c}	82.5±1.2^{c}	84.5±0.2^{b}	86.4±0.3^{a}	86.0±0.2^{a}	86.5±0.6^{a}
- peak viscosity	3335±32^{d}	3659±68^{c}	3846±24^{a}	3766±80^{b}	3630±12^{c}	3305±23^{d}	3271±21^{d}
- trough	2308±147^{c}	2440±40^{b}	2601±60^{a}	2633±43^{a}	2574±63^{a}	2227±20^{c}	1936±42^{d}
- final viscosity	3433±126^{e}	3619±44^{d}	3840±40^{c}	4239±54a	4124±35^{b}	3710±20^{d}	3621±14^{d}
- breakdown	1027±140^{c}	1219±71^{ab}	1245±64^{ab}	1133±49^{bc}	1056±52^{c}	1078±21^{c}	1334±27^{a}
- setback	98.0±125.3^{c}	-40.0±99.2^{d}	-5.5±40.8^{cd}	473.2±44.7^{a}	494.0±22.9^{a}	405.2±7.8^{ab}	350.0±8.5^{b}

Means (± SD) followed by the same letters in a row are not significantly different by DMRT (P<0.05)

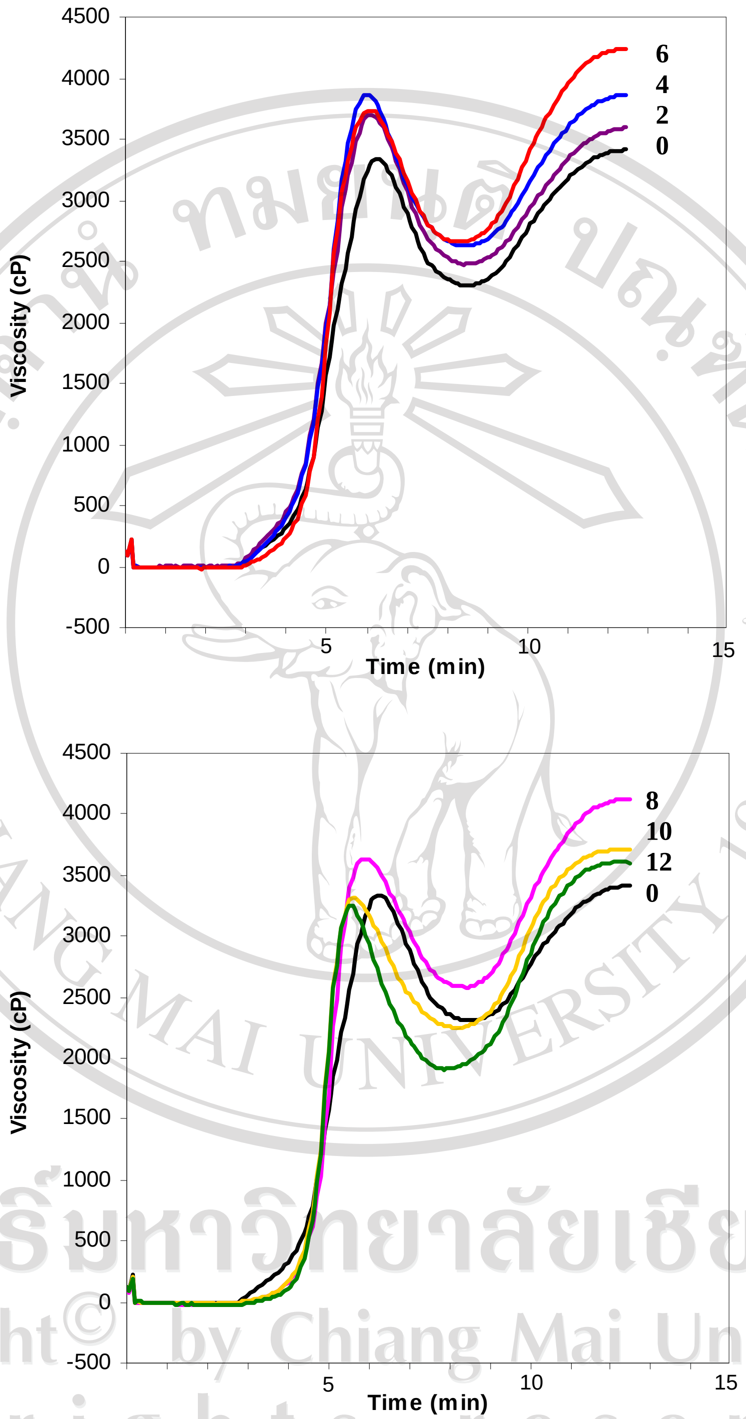

Figure 5.1 **RVA viscograms of flour obtained from rice cv. KDML 105 after storage as paddy at ambient condition for 12 months. Numbers indicate month of storage.**

affected by storage duration (Meullenet *et al*., 2000). In this current study, rice from longer storage had a tendency to have harder texture and the change in cooked rice hardness was observed only after the rice was stored over 10 months. However, increase in hardness value was not much as referred to fresh rice hardness (3.9% increases). In contrast, significant decrease of adhesiveness and increase in springiness was found at a shorter time of storage. The 4-month stored rice had significantly lower value of adhesiveness while it was 6 months for springiness to find significant increase. The adhesiveness was decreased by 26.9%, from the value of 647 at first month of storage to 473 in the fourth month, and the springiness increased by 11.5% in the sixth month sample. Decrease in adhesiveness of cooked rice with time of storage was previously reported (Tamaki *et al*., 1993; Chrastil, 1994; Champagne *et al*., 1998; Meullenet *et al*., 2000). For cohesiveness, there was no changing trend and no statistical difference was detected among cohesiveness values over 12 months of storage. The results of this study indicated that adhesiveness of rice cv. KDML 105 was the attribute most affected by storage time. Martin and Fitzgerald (2002) suggested that increase in disulphide bonding of rice storage protein could affect amount of water absorbed by rice during cooking and would influence texture of cooked rice.

5.3.3 Kernel Elongation during Storage

Kernel elongation is an attribute of cooking quality of aged rice. This attribute was determined over the 12-month storage period in this study and the values of kernel elongation as affected by storage time are shown in Figure 5.2. It was found that only 12-month stored rice had significantly longer cooked kernel comparing to that of fresh rice. The freshly harvested cooked kernel was 9.87 mm which was increased by 9.2% to 10.78 mm in the 12-month stored sample. The increase might be attributed to the lower susceptibility to disintegration during cooking of rice kernel from 12-month aged rice sample. Result of this study agreed with results previously reported by Chrastil (1990a; 1992) in which swelling percentage of cooked rice kernel increased during storage of rice.

Table 5.2 Texture profile analysis attributes of KDML 105 cooked rice during storage as paddy for 12 months at ambient temperature.

Textural properties	Storage time (months)						
	0	2	4	6	8	10	12
- hardness (g) (P=0.075)	14960±440^{ab}	14853±297^{ab}	14462±458^{b}	14775±527^{ab}	14915±558^{ab}	15546±245^{a}	15488±361^{a}
- adhesiveness (g. mm)	647±28.51^{b}	581±88.86^{b}	473±66.10^{a}	417±9.24^{a}	401±29.64^{a}	440±33.41^{a}	436±80.32^{a}
- springiness	0.191±.0.020^{c}	0.205±0.011^{bc}	0.187±0.007^{c}	0.213±0.013^{ab}	0.224±0.009^{ab}	0.207±0.008b^{c}	0.231±0.007^{a}
- cohesiveness	0.566±0.028	0.561±0.005	0.541±0.013	0.547±0.002	0.558±0.009	0.575±0.018	0.555±0.007

Means (± SD) followed by the same letters in a row are not significantly different by DMRT (P<0.05)

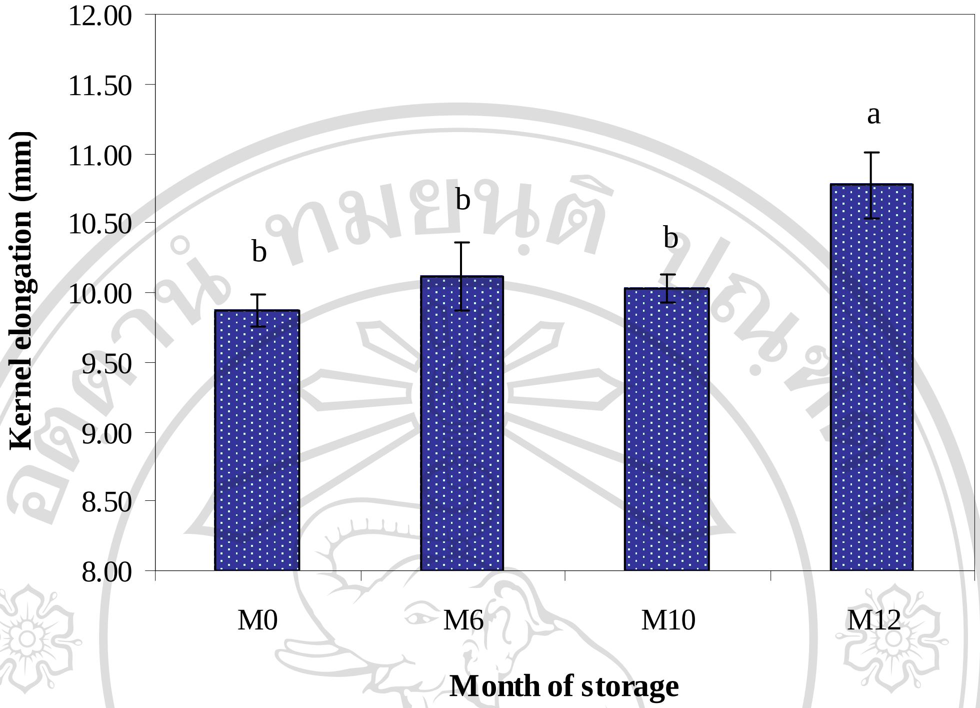

Figure 5.2 Kernel elongation of cooked rice of KDML105 paddy stored in ambient condition for a period of 12 months. Vertical bars (±SD) with the same letters are not significantly different by DMRT (*P*<0.05).

5.3.4 Rice Color Change during Storage

Color values (*L**, *a**, *b**, chroma and hue angle) of milled rice from stored paddy over 12-month storage period are presented in Table 5.3. Storage time changed the rice to be yellowish as indicated by the increase in *b**value. The yellow value (*b**) changed from 7.00 in fresh rice to 9.85 in the 12-month stored sample. Redness was not affected by storage whereas all other color parameters were significantly changed. The value of color brightness varied between 47.78 and 52.47, with the samples stored for 2 and 4 months having lower brightness value. Milling operation might contribute to this variation. Chroma was increased from the initial value of 7.03 to 9.90 in the 12-month rice and hue angle decreased from 97.5 to 95.75 after 12-month storage. Changes of these values indicated that the 12-month rice sample had

Table 5.3 Color parameters (*L, *a**, *b**, chroma and hue angle) of KDML 105 milled rice during storage as paddy for 12 months at ambient temperature.**

Color parameters	Storage time (months)						
	0	2	4	6	8	10	12
- brightness (*L** value)	51.09±1.53[ab]	47.78±1.05[d]	48.53±0.67[cd]	50.22±1.07[bc]	52.47±1.55[a]	51.47±1.06[ab]	50.17±0.73[bc]
- redness (*a** value)	-0.91±0.06	-1.00±0.07	-0.96±0.04	-0.99±0.04	-0.96±0.06	-1.03±0.02	-0.99±0.09
- yellowness (*b** value)	7.00±0.11[f]	8.74±0.03[de]	9.36±0.25[bc]	9.44±0.25[b]	8.52±0.15[e]	8.99±0.08[cd]	9.85±0.40[a]
- chroma	7.03±0.06[e]	8.80±0.02[cd]	9.41±0.25[b]	9.49±0.25[b]	8.57±0.14[d]	9.04±0.08[c]	9.90±0.39[a]
- hue angle	97.45±0.48[a]	96.51±0.49[b]	95.85±0.26[b]	95.98±0.33[b]	96.47±0.45[b]	96.56±0.16[b]	95.75±0.71[b]

Means (± SD) followed by the same letters in a row are not significantly different ($P<0.05$)

degraded and its color became more yellowish and reddish. Soponronnarit *et al.* (2008) reported decrease in whiteness of rice cv. KDML 105 during storage for 6 months in paddy form and Sirisoontaralak and Noomhorm (2007) found an increase in *b**value (yellowness) of rice cv. KDML 105 during study for 12-month storage duration. For better visualization of the color change, the actual color of freshly harvested milled rice and rice stored for 6 and 12 months are shown in Figure 5. 3.

*L**: 51.09; *a**:-0.91; *b**:7.00 | *L**: 50.22; *a**:-0.99; *b**:9.44 | *L**: 50.17; *a**:-0.99; *b**:9.85

Fresh rice (control) | **6-month stored rice** | **12-month stored rice**

Figure 5.3 Color of freshly harvested milled rice (control) and rice stored as paddy for 6 and 12 months at ambient condition.

5.3.5 Loss of 2-Acetyl-1-pyrroline during Storage

Concentration of 2-acetyl-1-pyrroline of rice samples decreased dramatically during storage as paddy in ambient condition (prevailing storage method in Thailand). The value was decreased by 58.7% after storage for 12 months, from the initial value of 5.57 ppm in first month to 2.30 ppm in the 12-month stored samples (Figure 5.4).

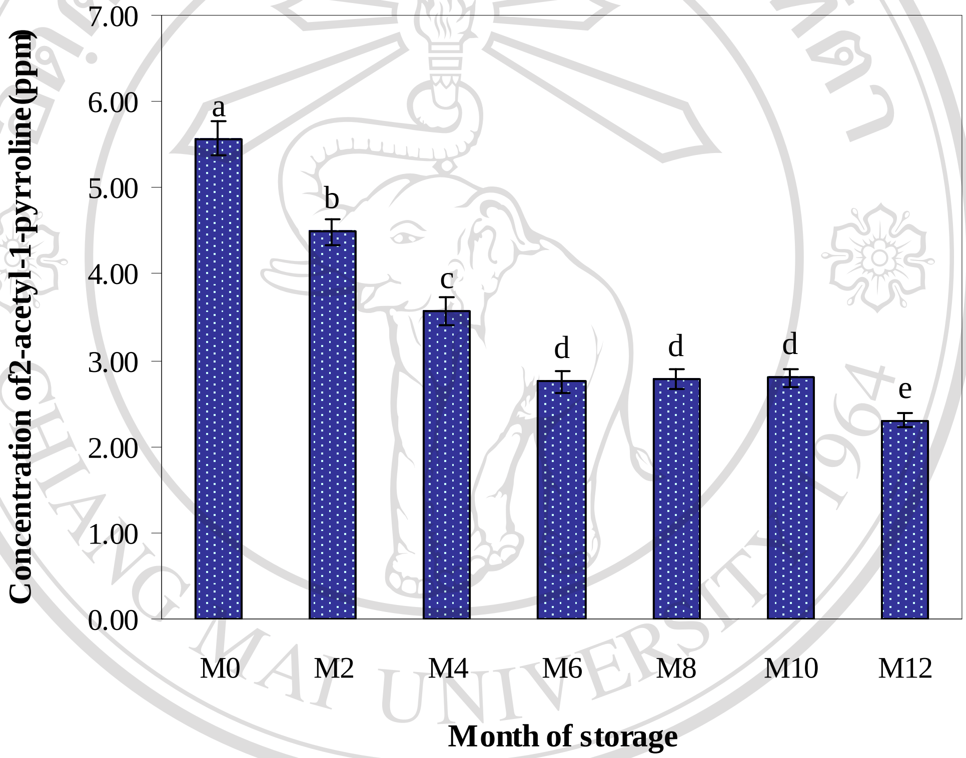

Figure 5.4 Change in 2-acetyl-1-pyrroline concentration of KDML105 milled rice after storage as paddy in ambient condition for a period of 12 months. Vertical bars (±SD) with the same letters are not significantly different by DMRT (*P*<0.05).

Similar results were reported on the decrease of 2-acetyl-1-pyrroline from paddy cv. KDML 105 during storage in ambient condition (Wongpornchai *et al*., 2004; Yoshihashi *et al*., 2005). In this present study, rate of 2-acetyl-1-pyrroline decrease was rapid in the first 4 months, then leveled off up to month 10 in which 2-acetyl-1-pyrroline began to decrease again to the lowest value at storage end. This trend of change might be attributed to the presence of 2-acetyl-1-pyrroline in rice which had two forms, starch-bound form and free form, as suggested by Yoshihashi *et al* (2005), with the free form would readily volatilize from the stored rice.

5.3.6 Development of *n*-Hexanal during Storage

The relative amount of key off-odor compound, *n*-hexanal, generated during natural aging was quantified in comparison with that of the freshly harvested rice sample. During storage, the stored rice showed increase in area ratios of *n*-hexanal/DMP (Figure 5.5). The ratios were observed to increase with storage time

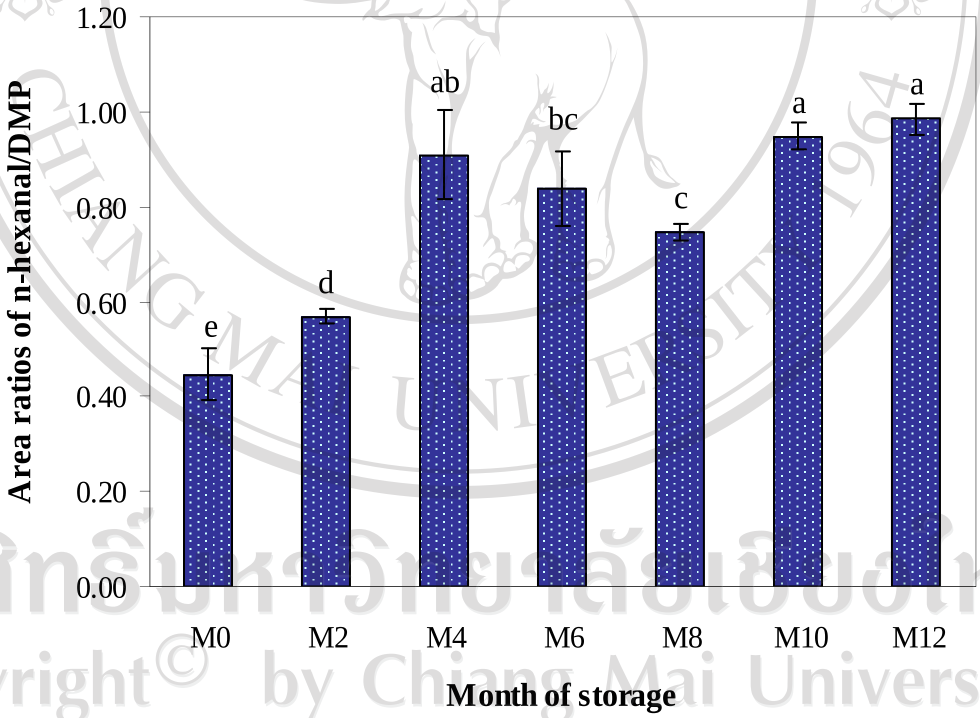

Figure 5.5 Change in area ratios of n-hexanal/DMP of KDML105 milled rice after storage as paddy in ambient condition for a period of 12 months. Vertical bars (±SD) with the same letters are not significantly different by DMRT (*P*<0.05).

from the initial value of 0.45 to 0.99 in the 12-month stored sample. Consistent increase of *n*-hexanal of rice cv. KDML 105 stored in paddy form for 10 months was previously reported by Wongpornchai *et al* (2004). Variation of results was observed in this experiment in which the 8-month sample had lower value of *n*-hexanal. The variation may be attributed to the fluctuation of storage environment that could impact on grain moisture content and on the subsequent milling process. However, the results from this current study showed that stored samples had greater area ratio of *n*-hexanal as compared to that of fresh rice. Increase in *n*-hexanal during storage of rice was attributed to the deterioration of the rice lipids (Zhou et al., 2002).

5.4 Conclusions

The results derived from this experiment revealed that physico-chemical properties related to cooking and eating quality of freshly harvested rice changed by time of storage. The storage time affected pasting property by increasing pasting temperature and pasting viscosity; textural property by increasing cooked rice hardness, springiness and decreasing adhesiveness; increased kernel elongation and *b**value (yellowness); of stored rice. Storage also decreased 2-acetyl-1-pyrroline content and increased the relative amount of *n*-hexanal of the stored samples. The results in this study were useful for comparing to those rice samples used in the study of the effect of accelerated aging treatments discussed in Chapter 4.