CHAPTER 3
EFFECTS OF TEMPERATURE AND EXPOSURE DURATION ON PASTING PROPERTY, TEXTURAL PROPERTY AND COLOR OF FRESHLY HARVESTED RICE CV. KDML 105

3.1 Introduction

Preference for stored rice by Asian consumers has been documented (Juliano, 1985b). This makes clear that textural property is very important and be another major factor for purchase decision by these people. As already known, storage takes time and is costly, and moreover, can induce changes in the stored rice to be both desirable and undesirable physico-chemical characteristics. This change depended on its storage environment and management (Perdon *et al*., 1997; Pearce *et al*., 2001; Zhou *et al*., 2003; Wongpornchai *et al*., 2004). Searching for postharvest technologies that could enhance aging process in rice by short-time processing and have minimal cost is therefore an attraction. A technique called accelerated aging has been reported to improve some rice quality attributes that could be comparable to those of naturally-aged rice. This method can accelerate rate of aging in freshly harvested paddy by using wet (Gujral and Kumar, 2003) or dry (Soponronnarit *et al*., 2008) heat treatments. Factors involving in the success of these practices are temperature, time and grain moisture content. However, the practices may result in lower head rice yield and more yellow color of the resulting milled rice product.

For this present experiment, it was conducted to investigate changes in rice physico-chemical properties when accelerated aging practice is done on milled rice. This method enhanced aging by heating milled rice that is loaded in a closed system to prevent loss of water from its kernel. It can be a potential process since it has several advantages over that of paddy. However, there have been only few reports on its effect of improving physico-chemical properties that relate to quality factors of the milled and cooked rice produce. Thus, the objective of this study was to evaluate the effects of temperature and exposure duration on pasting property, textural property and color of the freshly harvested KDML 105 milled rice.

3.2 Materials and Methods

3.2.1 Rice Samples and Preparations

Rice cv. KDML 105 was grown in 2004 season at Lampang Agricultural Research and Training Center, Rajamangala University of Technology Lanna, Lampang. It was harvested at maturity by hand, left to dry 2 to 3 days in the field and then threshed to paddy. The freshly harvested paddy sample (having moisture content (MC) of approximately 14%) was then dehulled by a McGill sample sheller and the resulting brown rice was milled 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 stored at room temperature for subsequent treatments. A portion of the head rice sample was separated and determined for its physico-chemical properties. Protein (N×5.95) and lipid contents of the head rice as determined by AOAC (1999) standard methods were 5.87 and 0.74%, respectively. The apparent amylose content was 17.22% (w/w) as determined by the method of Juliano *et al*. (1981). The MC of milled rice sample was 13.3% (wet basis, wb) as determined by oven method (103^{o}C for 17 hr).

3.2.2 Accelerated Aging Treatments

Three replicates of 370 g of freshly harvested milled rice samples were placed in aluminum containers (11 cm height X 8.5 cm diameter) and covered with heavy-duty aluminum foil. The rice samples were then exposed to three different temperatures (100, 110 and 120^{o}C) for four exposure durations (15, 30, 45 and 60 min, except for 100^{o}C heating an addition of 90 min exposure was included) in an automatic autoclave (SS-320, Tomy Seico Co. Ltd., Wako, Saitama, Japan). The change in milled rice temperature during accelerated aging treatment was recorded using a data logger. Sensors were set to record temperature at the center of the rice containers and mean reported was an average of three replications. Figure 3.1 shows the temperature profiles of three extreme accelerated aging treatments. After exposure, the rice samples were left covered in the aluminum containers and cooled for about 2 hr at 21^{o}C. The rice samples were then poured onto screen and weighed for observing weight loss before placing in zip-locked plastic bag. Since, rice pasting

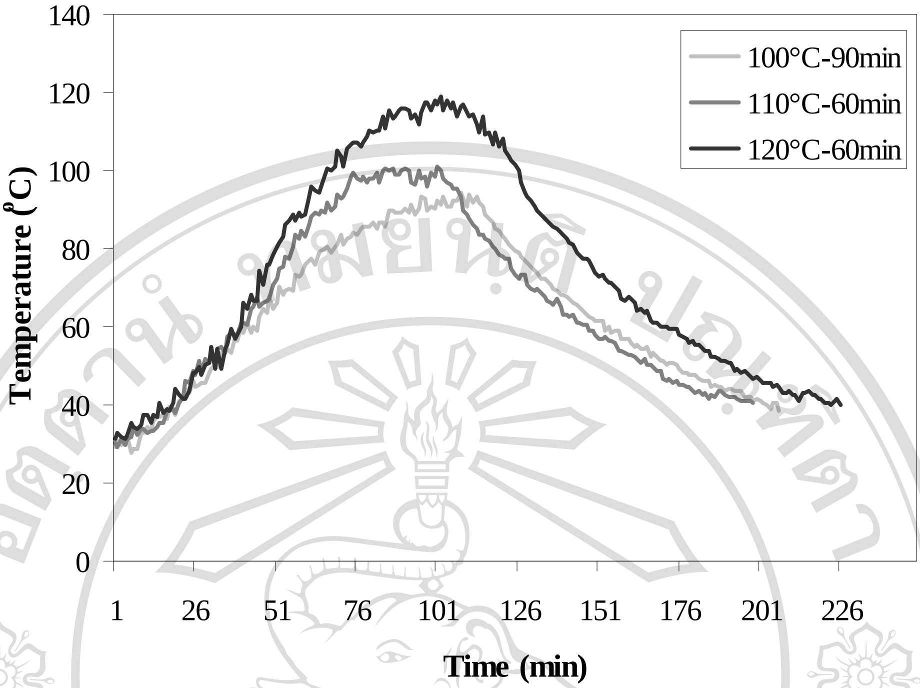

Figure 3.1 Temperature profiles of three extreme accelerated aging treatments. Data recorded at the center of milled rice containers.

properties change rapidly during first six weeks after harvest (Perdon *et al*., 1997), to ensure that the changes observed were due to the impact from treatments and not storage effects, the rice sample sealed in zip-locked plastic bags were stored at 4°C until the time of measurements.

3.2.3 Determination for Pasting Property

A Rapid Visco Analyser (RVA) (model 4, Newport Scientific, Warriewood, NSW, Australia) was used to measure pasting property of rice samples. Samples were ground in a Cyclotec 1093 sample mill (Tecator, Hogenas, Sweden) fitted with a 0.5 mm screen and the resulting flour were stored in zip-locked plastic bags at 4°C. Prior to the analysis, moisture content of the flour samples was determined by drying at 130°C for 2 hours. Analysis was then performed by placing a canister containing an aqueous solution of 3 g flour (weight adjusted to 12 % flour moisture content) and 25 g of distilled water (adjusted to correct for flour MC) into the RVA instrument. The measurements were performed using the profile outlined by Approved Method 61-02 (AACC, 2000). The test profile has a starting temperature of 50°C, which was held for 1 min, raised to 95^{o}C in 3.8 min, held for 2.5 min, cooled to 50^{o}C in 3.8 min, and held for 1.4 min. Stirring speed was 960 rpm for the first 10 sec (homogenization of flour sample) and 160 rpm for the remainder of the test period. The RVA parameters were as follows: peak viscosity (PV) = highest viscosity during heating; trough (TR) = lowest viscosity after cooling started; breakdown (BD) = peak viscosity minus trough; final viscosity (FV) = maximum viscosity after the temperature had returned to 50^{o}C; setback (SB) = final viscosity minus peak viscosity; pasting temperature (PA) = temperature when the rate of increase in viscosity reaches 36 centipoises (cPs) in 6 sec, effectively the beginning of the rapid increase towards peak viscosity. Each analysis was performed at least twice and all RVA parameters were recorded and analyzed employing Thermocline software. The RVA viscogram of KDML105 is presented in Figure 3.2.

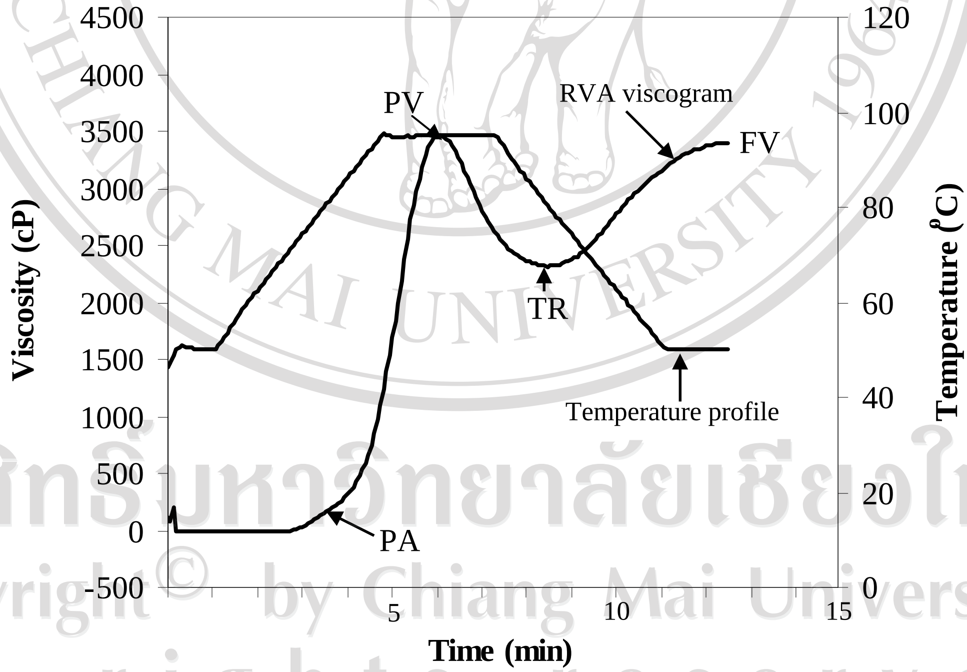

Figure 3.2 The RVA viscogram of flour from milled rice cv. KDML105 and determination of its parameters. PV; peak viscosity: TR; trough: FV; final viscosity: PA; pasting temperature (^{o}C).

3.2.4 Determination for Textural Property of Cooked Rice

The effects of accelerated aging treatments on cooked rice textural properties were measured and investigated. Textural properties of freshly-harvested and accelerated-aging cooked rice samples were determined using a bench-top TA-XT*plus* Texture Analyzer (Texture Technologies Corp., Scarsdale, NY). A two-cycle compression, force versus distance was programmed and a 40-mm diameter cylinder probe (SMS P/40) connecting with a 100-mm probe adapter (A/D 100) and attached to a 50 kg load cell (Texture Technologies Corp., Scarsdale, NY) was employed.

In this study, texture profile analysis (TPA) as described by Champagne *et al*. (1998) was performed with some modification. The probe was set at 5 mm above the base platform of the instrument and allowed to travel 4.9 mm, return, and repeat at a crosshead speed of 1 mm/sec. Force in grams required to compress the sample was recorded as a function of time. Rice samples (250g to 424g of water) were completely cooked in household electronic rice cookers (1.1 liter capacity, Sharp model KSH-111), followed by a 10-min warming period. Measurement was done immediately at the end of the 10-min warming period. Five replicated measures were made on each cooked rice sample and were made finished within 10 min while the sample was kept in the warm mode of the rice cooker. The sample was taken by a spoon and the top 1-cm layer was discarded. Immediately, 10 unbroken cooked kernels were transferred, and arranged in a single grain layer on the base platform, and subjected to texture profile analysis (TPA). The resulting 2-cycle test curves were then analyzed, using the Texture Exponent 32 software (Stable Micro Systems, Godalming, UK) and the TPA parameters recorded were hardness or firmness (maximum positive force of first compression), adhesiveness (negative force to pull probe from sample), cohesiveness (ratio of area under second compression to area under first compression), springiness (ratio of distance traveled by probe on the two curve; relates to sample recovery after first compression) as shown in Figure 3.3.

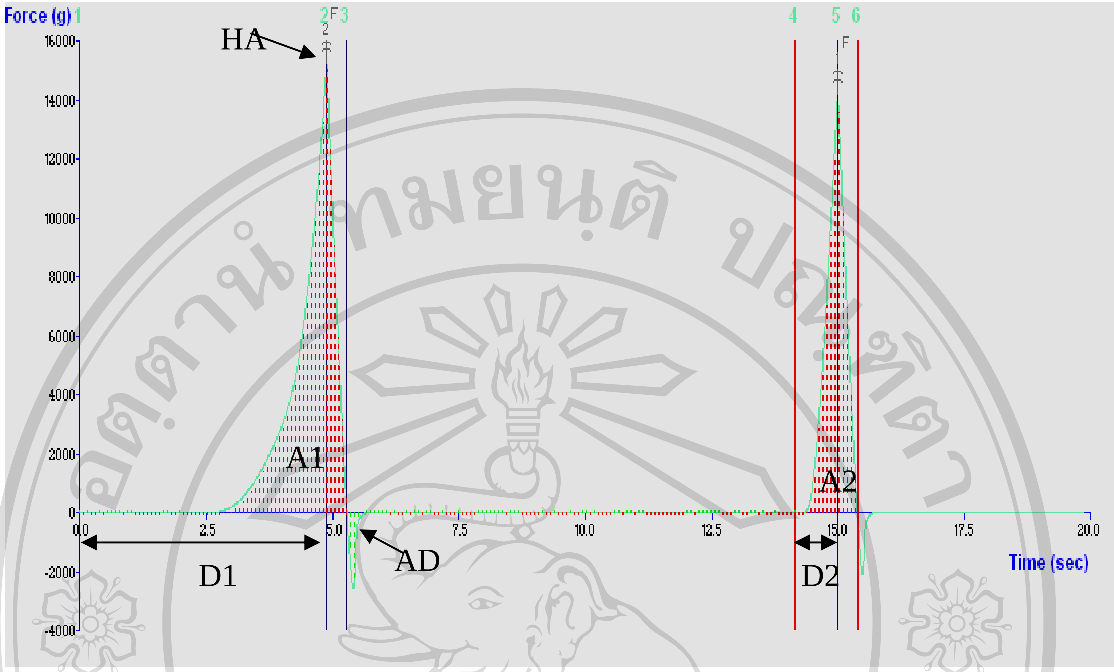

Figure 3.3 A typical texture profile analysis (TPA) curve obtained from Texture Analyzer. TPA parameters recorded: HA, hardness (g) (maximum positive force of first compression); AD, adhesiveness (area of the negative force to pull probe from sample); cohesiveness (CO) (ratio of area under second compression (A2) to area under first compression (A1)); springiness (SP) (ratio of distance traveled by probe on second compression (D2) to distance traveled by probe on first compression (D1); relates to sample recovery after first compression).

3.2.5 Determination for Rice Color

The colors of milled rice samples were measured employing Hunterlab color meter (ColorQuest® XE, Hunterlab, Reston, VA, USA), using the CIE (Commission Internationale de l' Eclairage, 1976) *L** *a** and *b** color system where *L** described brightness, *a** is redness and *b** is yellowness. The measurement was performed in triplicate. Calibration was done prior to the measurement by using standard white and green color tile. Values derived were converted to hue angle (tan^{-1} b/a) and chroma $(a^2+b^2)^{1/2}$ as described by McLellan *et al*. (1995).

3.2.6 Statistical Analysis

Data on physico-chemical properties in terms of pasting property, textural property and color parameters of the rice samples were analyzed, using analysis of variance (ANOVA) to determine the treatment effects. Duncan's multiple range test (P<0.05) was done to compare treatment means. Pearson's correlation coefficients (r) between all variables and regression analysis were performed and analyzed.

3.3 Results and Discussion

3.3.1 Pasting Property

The effects of exposure temperatures and durations on pasting property of freshly harvested KDML 105 rice were examined through RVA viscograms and their pasting parameter values are presented in Table 3.1. After exposure to different temperatures and duration times, the RVA pasting curve changed dramatically. The flour samples obtained from various accelerated aging treatments performed their pasting curves in different manner. Thus, for a better demonstration of the significant different changes caused by the accelerated aging treatments, their representative viscograms are illustrated in Figure 3.4.

Temperature and exposure duration significantly affected pasting property of the rice samples when the rice had received sufficient heat. In 100^{o}C aging treatment, the RVA pasting curves of the 15 and 30 min exposure samples did not differ from fresh rice (control), except they had higher pasting temperature, so their pasting curves were not included in Figure 3.4. However, the data suggested that pasting temperature was the RVA parameter most sensitive to aging. The effect of 100^{o}C heating temperature was found after exposure time was expanded to 45 min or longer. At these exposures, their RVA pasting curves were clearly separated from the fresh rice curve which indicated that a certain level of exposure duration was required to age the freshly harvested rice. Comparison between exposure times, 90 min was the most severe treatment which could change fresh rice to become rice of having aged characteristic (as measured in terms of pasting property). The RVA parameters of 90

Table 3.1 RVA viscosity parameters of flour from freshly harvested milled rice cv. KDML 105 as affected by accelerated aging factors (temperatures and exposure durations).

Temperature –time (^{o}C-min)	RVA viscosity parameters (cP)					
	Pasting temp. (^{o}C)	Peak viscosity	Trough	Final viscosity	Breakdown	Setback
Fresh rice (control)	74.5±1.2^{h}	3361±110^{b}	1833±115de	2909± 139^{e}	1527± 6^{abc}	-452±29^{h}
100-15	79.5±4.4^{g}	3445±188^{ab}	1878±105^{bcde}	3012±94^{e}	1567± 133^{abc}	-433±131^{h}
100-30	81.1±1.6^{fg}	3367±36^{b}	1808±26^{e}	2941±28^{e}	1559± 62^{abc}	-426±36^{h}
100-45	82.0±1.3^{efg}	3447±97^{ab}	1814±39^{e}	3013±65^{e}	1633± 60^{ab}	-435±35^{h}
100-60	82.4±0.7^{ef}	3546±59^{a}	1871±77^{bcde}	3212±62^{d}	1675± 40^{a}	-334±34^{gh}
100-90	84.6±0.6^{de}	3454±70^{ab}	1977±111^{abcd}	3411±137^{c}	1478± 168^{bc}	-43±194^{f}
110-15	81.9±1.0^{efg}	3430±64^{ab}	1797±73^{e}	2991±76^{e}	1633± 13^{ab}	-439±24^{h}
110-30	84.2±0.1^{de}	3417±64^{ab}	1865±55^{cde}	3236±5^{d}	1552± 17^{abc}	-180±64^{fg}
110-45	86.2±0.9^{cd}	3152±72^{cd}	2027±69^{ab}	3572±67^{b}	1126± 124^{d}	420±137^{e}
110-60	86.6±0.4^{bcd}	3073±79^{d}	2057±65^{a}	3677±44^{ab}	1016± 103^{d}	603±93^{d}
120-15	83.9±1.1^{de}	3289±37^{bc}	1841±114de	3195±120^{d}	1448± 123^{c}	-95±130^{f}
120-30	88.2±0.6^{abc}	2502±82^{e}	2004±52^{abc}	3608±36^{b}	498± 89^{e}	1106±105^{c}
120-45	89.1±0.5^{ab}	2301±11^{f}	2055±25^{a}	3789±37^{a}	246± 30^{f}	1488±44^{b}
120-60	90.3±0.7^{a}	2045±163^{g}	1923±117^{abcde}	3730±163^{ab}	112± 47^{f}	1684±22^{a}

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

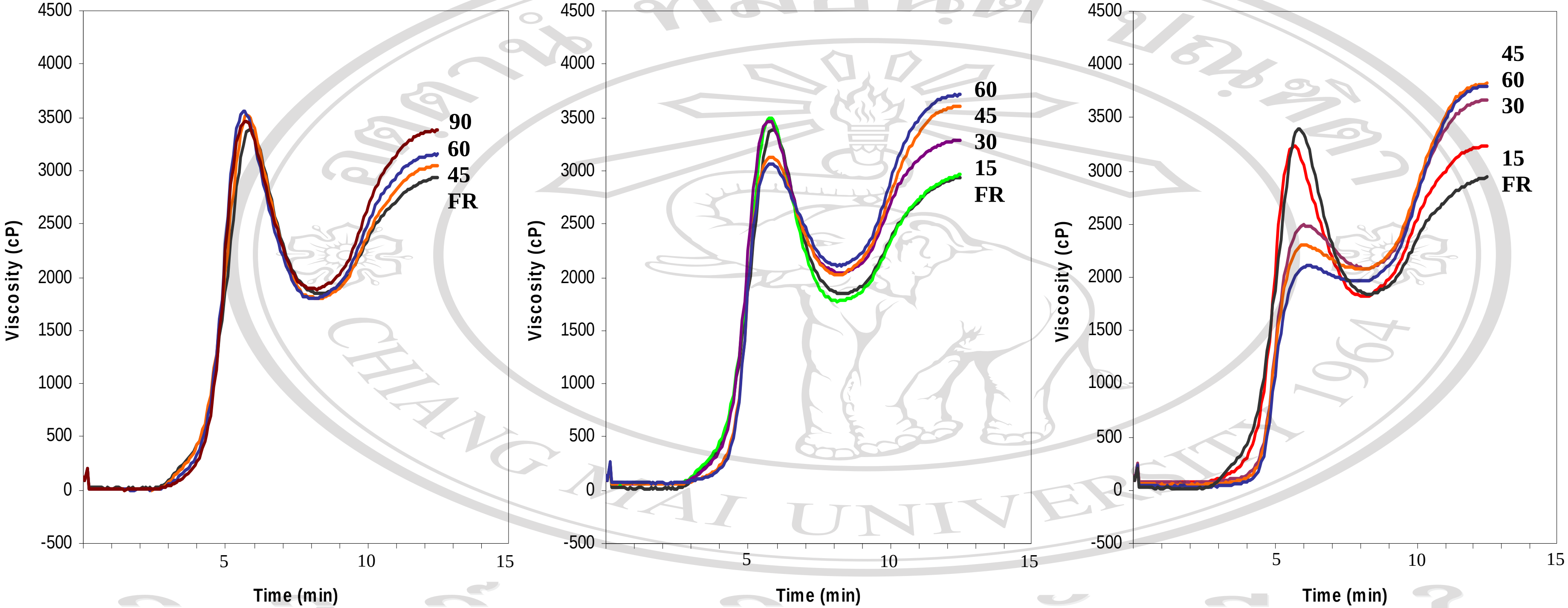

Figure 3.4 Change in RVA viscosity of flour from freshly harvested milled rice cv. KDML 105 as affected by accelerated aging factors (temperatures and exposure durations). Number attached to viscogram indicate exposure time (min); FR: fresh rice.

min sample such as pasting temperature, final viscosity and setback were significantly higher than those of samples receiving shorter exposure treatments and fresh rice. The pasting temperature increased from 74.5^{o}C (fresh rice) to 84.6^{o}C, final viscosity from 2909 to 3411 cPs and setback value from -452 to -43. There was an increasing trend of peak viscosity in shorter exposure treatments, and then followed by a decrease after receiving longer exposure time. The 90 min heated rice sample had slightly lower peak viscosity than rice heating at 60 min and had also higher trough values than rice heating at 30 and 45 min. These results explained for its lower breakdown value. Decreases in peak viscosity and breakdown during natural storage of rice were reported and the latter was noted as the RVA attribute most affected by aging (Zhou *et al*., 2003). Sowbhagya and Bhattacharya (2001) also reported that breakdown was negatively correlated with time of storage while setback was positively correlated. In this study, strong negative correlation between breakdown and setback of the accelerated aging rice was found. These RVA parameters may probably be used as aging indicators in processing of accelerated aging rice.

In 110^{o}C and 120^{o}C aging treatments, pasting temperature, trough, final viscosity and setback increased while peak viscosity and breakdown decreased. These values increased/decreased with expanding exposure duration. There was no increase in peak viscosity observed in rice aging with these exposure temperatures. This was probably attributed to the high temperature and long interval duration (15 min) used for aging process which may have obscured the rise in peak viscosity. Although, respond to exposure duration of rice heated in 110^{o}C and 120^{o}C was in a similar pattern, their magnitude of change was very different (Table 3.1) with the 120^{o}C sample showing faster and greater degree of aging effect. The RVA parameters of sample heated at 120^{o}C for 30, 45 and 60 min such as peak viscosity, breakdown, setback and pasting temperature changed in a greater magnitude as compared to those heated with the same exposure duration in the 110^{o}C treatment. For rice heating with 110^{o}C, all values of its RVA parameters significantly differed from the fresh rice sample after it was aged for 45 min or longer whereas in the 120^{o}C treatment, it began with shorter time (30 min). Exposure of milled rice to higher temperature or longer exposure time resulted in the progressive decrease of peak viscosity and breakdown which indicated that the freshly harvested rice sample was already aged. The higher and longer exposure temperature was the higher degree of aging of the rice. Aging process of naturally-stored rice, as studied via amylograph using Barbender (Perdon *et al*., 1997) and Rapid Visco Analyser (Zhou *et al*., 2003), was accelerated at higher storage temperature. Results from this study indicated the importance of the temperature and exposure duration factors on pasting parameters and the information derived could be extracted and useful to select suitable aging indicator in producing aged rice from freshly harvested rice.

3.3.2 Textural Property

Freshly harvested and the corresponding accelerated aging rice samples were subjected to texture profile analysis (TPA) to examine the effect of aging treatments on cooked rice textural property . TPA attributes such as hardness (also referred to as firmness), adhesiveness, springiness and cohesiveness were significantly affected by both the temperature levels and exposure time (Table 3.2). In general, hardness, springiness and cohesiveness increased with increasing temperature and exposure time. Although there were variations in springiness and cohesiveness values, the significant effect of temperature was observed. The hardness value of rice heated with 110 and 120^{o}C at all exposure durations were greater than those of fresh rice with an exception for sample heating at 110^{o}C for 15 min. The hardness of samples heating with 100^{o}C for 90 min and 110 and 120^{o}C for 60 min (the most severe treatment of each heating temperature) increased from its original value (hardness of fresh rice) by 5.8, 9.8 and 18.1%, respectively. Increase in small magnitude of hardness was attributed to the soft texture nature of the rice used in this study. For adhesiveness, the value decreased with increasing exposure temperature and time and the effect of aging treatment on adhesiveness was in greater degree than on hardness. Fresh rice had an adhesiveness value of 585 g. mm which was decreased by 42.9, 53.7 and 77.9% to 334, 271 and 129 g. mm for the samples aged at 100^{o}C for 90 min, 110^{o}C and 120^{o}C for 60 min, respectively.

Accelerated aging in paddy had been reported to increase hardness, springiness and cohesiveness while decrease adhesiveness of the resultant cooked

Table 3.2 Texture profile analysis attributes of cooked rice from freshly harvested rice cv. KDML 105 as affected by accelerated aging factors (temperatures and exposure durations).

Temperature –time (^{o}C-min)	Texture profile analysis attributes			
	Hardness (g)	Adhesiveness (g. mm)	Springiness	Cohesiveness
Fresh rice (control)	14175±79^{h}	585±44^{gh}	0.181±0.020^{de}	0.515±0.043^{bc}
100-15	14702±97^{efg}	626±58^{h}	0.183±0.035^{de}	0.571±0.012^{a}
100-30	14592±141^{fgh}	581±132^{gh}	0.188±0.056^{cde}	0.566±0.014^{a}
100-45	14322±315^{gh}	549±38^{gh}	0.180±0.035^{de}	0.564±0.063^{ab}
100-60	14327±295^{gh}	505±40^{ef}	0.181±0.016^{de}	0.490±0.083^{c}
100-90	14998±57^{def}	334±35^{cd}	0.172±0.088^{e}	0.554±0.070^{ab}
110-15	14523±483^{gh}	532±14^{gh}	0.184±0.081^{de}	0.568±0.016^{a}
110-30	15090±333de	495±62^{ef}	0.192±0.016^{cde}	0.542±0.039^{ab}
110-45	15870±117^{b}	341±27^{cd}	0.198±0.011^{bcd}	0.525±0.040^{ab}
110-60	15565±314^{bc}	271±44^{c}	0.192±0.088^{cde}	0.565±0.097^{a}
120-15	15391±128^{cd}	421±95de	0.208±0.011^{abc}	0.550±0.032^{ab}
120-30	15831±123^{b}	249±25^{bc}	0.216±0.024^{ab}	0.551±0.032^{ab}
120-45	16426±255^{a}	166±20^{ab}	0.223±0.012^{a}	0.566±0.030^{a}
120-60	16736±155^{a}	129±31^{a}	0.230±0.014^{a}	0.570±0.023^{a}

Means (± SD) followed by the same letters in a column are not significantly different by DMRT (P<0.05) milled rice (Gujral and Kumar, 2003). Increase in hardness and decrease in adhesiveness of cooked rice following storage time are the well known phenomena. In the present study, the same changing trend was found and was also confirmed by the strong correlation between hardness and adhesiveness (r = -0.86, P<0.0001) of the cooked rice samples after the freshly harvested milled rice samples had received accelerated aging treatments. The result indicated that accelerated aging technique could mimic natural aging process to yield rice of the same textural property.

3.3.3 Change in Rice Color

Effects of temperature and exposure duration on color parameters of milled rice such as brightness (L^*), redness (a^*), yellowness (b^*), chroma and hue angle values are presented in Table 3.3. Brightness of rice color was not affected by the accelerated aging treatments (temperature level and exposure duration). However, aging treatments significantly changed redness, yellowness, chroma and hue angle values of the heated rice samples with the magnitude of change depending on the severity of aging treatment. Color of freshly harvested milled rice appeared to be more yellowish after receiving aging treatments. The yellow (b^*) value increased with increasing temperature and time, and the magnitude of increase was larger at the higher temperature treatment. The b^* value of fresh rice increased from 7.00 to 7.58 after heating with 100^{o}C for 90 min, and increased to the higher values (8.36 and 10.23) in the samples heating with 110 and 120^{o}C for 60 min. Increase in yellow color of the heated rice samples was mainly attributed to non-enzymatic Maillard reaction and the intensity of yellow color was determined by temperature level (heating rate) and time. From these data (which were the b^* values of the most severe condition of each temperature treatment), it was suggested that rice could be accelerated-aged without too much loss of its color appearance when compared to b^* value (9.49) of milled rice obtained from the 15-month naturally-stored paddy (data not shown in Table 3.3). Moreover, it suggested that accelerated aging with lower heating temperature could provide less yellow color aged rice.

In contrast to yellowness, redness of milled rice samples (as indicated by a^*value) was less affected by the aging treatments and there were only rice samples

Table 3.3 Color parameters (*L, *a**, *b**, chroma, and hue angle) of KDML 105 freshly harvested milled rice as affected by accelerated aging factors (temperatures and exposure durations).**

Temperature –time (^{o}C-min)	Color parameters				
	L * value (brightness)	*a** value (redness)	*b** value (yellowness)	chroma	hue angle
Fresh rice (control)	51.05±0.66	-0.94±0.063^{bc}	7.00±0.268^{f}	7.06±0.265^{f}	97.73±0.574^{ab}
100-15	51.66±0.77	-1.01±0.060^{cd}	7.13±0.085^{ef}	7.20±0.094^{ef}	98.08±0.415^{ab}
100-30	51.69±0.42	-0.98±0.025^{cd}	6.89±0.073^{f}	6.96±0.070^{f}	98.17±0.233^{a}
100-45	51.37±0.55	-1.02±0.026^{cd}	6.95±0.154^{f}	7.02±0.155^{f}	98.38±0.171^{a}
100-60	51.99±1.10	-1.03±0.049^{cd}	7.44±0.131^{de}	7.51±0.133^{de}	97.87±0.347^{ab}
100-90	51.92±0.65	-1.04±0.021^{cd}	7.58±0.096^{d}	7.65±0.094^{d}	97.83±0.264^{ab}
110-15	51.41±0.67	-1.03±0.022^{cd}	6.88±0.266^{f}	6.95±0.267^{f}	98.52±0.237^{a}
110-30	51.46±1.15	-1.04±0.024^{cd}	7.30±0.022^{def}	7.37±0.026^{def}	98.18±0.139^{a}
110-45	51.43±0.95	-1.09±0.033^{d}	8.02±0.149^{c}	8.10±0.148^{c}	97.74±0.244^{ab}
110-60	51.82±0.30	-1.05±0.029^{cd}	8.36±0.195^{c}	8.42±0.195^{c}	97.19±0.092^{bc}
120-15	51.88±0.18	-1.03±0.075^{cd}	7.46±0.064^{de}	7.53±0.074^{de}	97.88±0.538^{ab}
120-30	51.22±0.81	-1.03±0.021^{cd}	9.13±0.197^{b}	9.19±0.199^{b}	96.46±0.069^{c}
120-45	51.47±1.42	-0.85±0.166^{ab}	9.97±0.684^{a}	10.01±0.669^{a}	94.94±1.298^{d}
120-60	51.12±1.20	-0.74±0.137^{a}	10.23±0.046^{a}	10.26±0.048^{a}	94.20±0.738^{d}

Means (± SD) followed by the same letters in a column are not significantly different by DMRT (P<0.05) heating at 120^{o}C for 45 and 60 min which showed distinct redness values. The change in *a**values indicated that aging with these high severe conditions (120^{o}C for 45 and 60 min) could change the rice color to be more reddish which was not observed in the lower temperature or the shorter exposure duration treatments. Increase in chroma and decrease of hue angle values of rice from high severe aging treatments supported the changes in color of the extensive aged rice and gave us more information of aging effects on color changes. The lower hue angle indicated that the rice sample became more reddish which was not found in less-severe aging Therefore, discoloration caused by the aging treatments could be controlled by optimizing the temperature level and exposure time.

3.3.4 Relationship between Pasting Properties, Textural Properties and Color Parameters

Aging induces change in rice properties and these changes are interrelated. Analyses of correlations between pasting properties, textural properties and color parameters of rice samples in this study are presented in Table 3.4. The analyses indicated that all pasting parameters were significantly correlated (p = <0.001) and setback may possibly be considered to be the most important determinant of aging. Setback showed high correlation coefficients (r) with pasting temperature, peak viscosity, final viscosity and breakdown (r = 0.83, -0.96, 0.90 and -0.99, respectively) and showed moderate correlation with trough (r = 0.61). Change in setback was also strongly associated with change in textural properties and color parameters. Correlation coefficients between setback and textural properties such as hardness, adhesiveness and springiness were 0.91, -0.91 and 0.76, respectively, and setback with color parameters such as *b**, chroma and hue angle values were 0.97, 0.97 and -0.89, respectively. Correlation among textural properties also demonstrated that hardness was highly negatively correlated with adhesiveness (r = -0.86) and positively correlated with springiness (r = 0.73) while the latter two attributes were negatively correlated (r = -0.61). The analysis results revealed that setback, hardness and yellowness (*b**) were the parameters most strongly and frequently associated with the other rice property parameters. This suggested that setback, hardness or

Table 3.4 Pearson's correlation coefficients between textural property, pasting property, and color parameters of accelerated aging rice.

	HA	AD	SP	CO	PA	PV	TR	FV	BD	SB	L*	a*	b*	CH
AD	**-0.8591****													
SP	0.7305**	-0.6089**												
CO	0.2646	-0.0687	0.3076*											
PA	**0.8102****	**-0.8632****	0.6108**	0.1516										
PV	**-0.8577****	**0.8237****	**-0.7742****	-0.2170	-0.7401**									
TR	0.5474**	-0.6095**	0.3351*	0.0333	0.5039**	-0.4004**								
FV	**0.8439****	**-0.8980****	0.6181**	0.1156	**0.8302****	-0.7345**	**0.8333****							
BD	**-0.8847****	**0.8675****	**-0.7645****	-0.2014	**-0.7701****	**0.9806****	-0.5722**	**-0.8356****						
SB	**0.9123****	**-0.9136****	**0.7620****	0.1890	**0.8309****	**-0.9569****	0.6139**	**0.8999****	**-0.9877****					
L*	0.2802	-0.2755	0.2708	0.1088	0.3497*	-0.1862	0.1963	0.3024	-0.2086	0.2491				
a*	0.4417**	-0.3826*	0.4747**	0.1884	0.2697	-0.6429**	0.0001	0.2595*	-0.5754**	0.5241**	-0.4233**			
b*	**0.8783****	**-0.8900****	0.7172**	0.1611	**0.7962****	**-0.9366****	0.5727**	**0.8679****	**-0.9608****	**0.9733****	0.1555	0.5949**		
CH	**0.8790****	**-0.8914****	0.7160**	0.1602	**0.7982****	**-0.9356****	0.5746**	**0.8703****	**-0.9606****	**0.9736****	0.1600	0.5892**	**1.0000****	
HU	**-0.7827****	**0.7738****	-0.6894**	-0.1814	-0.6497**	**0.9084****	-0.4080**	-0.7122**	**0.9003****	**-0.8885****	0.0795	**-0.8309****	**-0.9362****	**-0.9336****

*,** = significant at P<0.05 and P<0.01, respectively.

HA: Hardness; AD: Adhesiveness; SP: Springiness; CO: Cohesiveness; PA: Pasting Temperature; PV: Peak Viscosity; TR: Trough; FV: Final Viscosity; BD: Breakdown; SB: Setback from Peak; CH: Chroma; HU: Hue Angle.

yellowness may probably be suitable to be used as aging indicator in processing of accelerated aging rice

Since changes in accelerated aging rice samples depended mainly on the functions of temperature and exposure time, and moreover, the correlation analysis among rice properties showed their close relationship, from this information, setback, hardness and yellowness were chosen to be aging predictors. Regression analysis was therefore conducted and the results indicated that the responses of rice, in terms of setback, hardness and yellowness, to temperature and exposure time could be adequately described by the quadratic equations as shown in Figure 3.5. The second-degree polynomial regression equations developed in this study could be utilized to estimate for temperature and time required for producing aged rice of desired properties. Regression slopes of the relationship and the coefficient of determinations (R^2) of setback, hardness and yellowness versus time were significantly greater in high temperature aging which was not obtained in low temperature aging treatments.

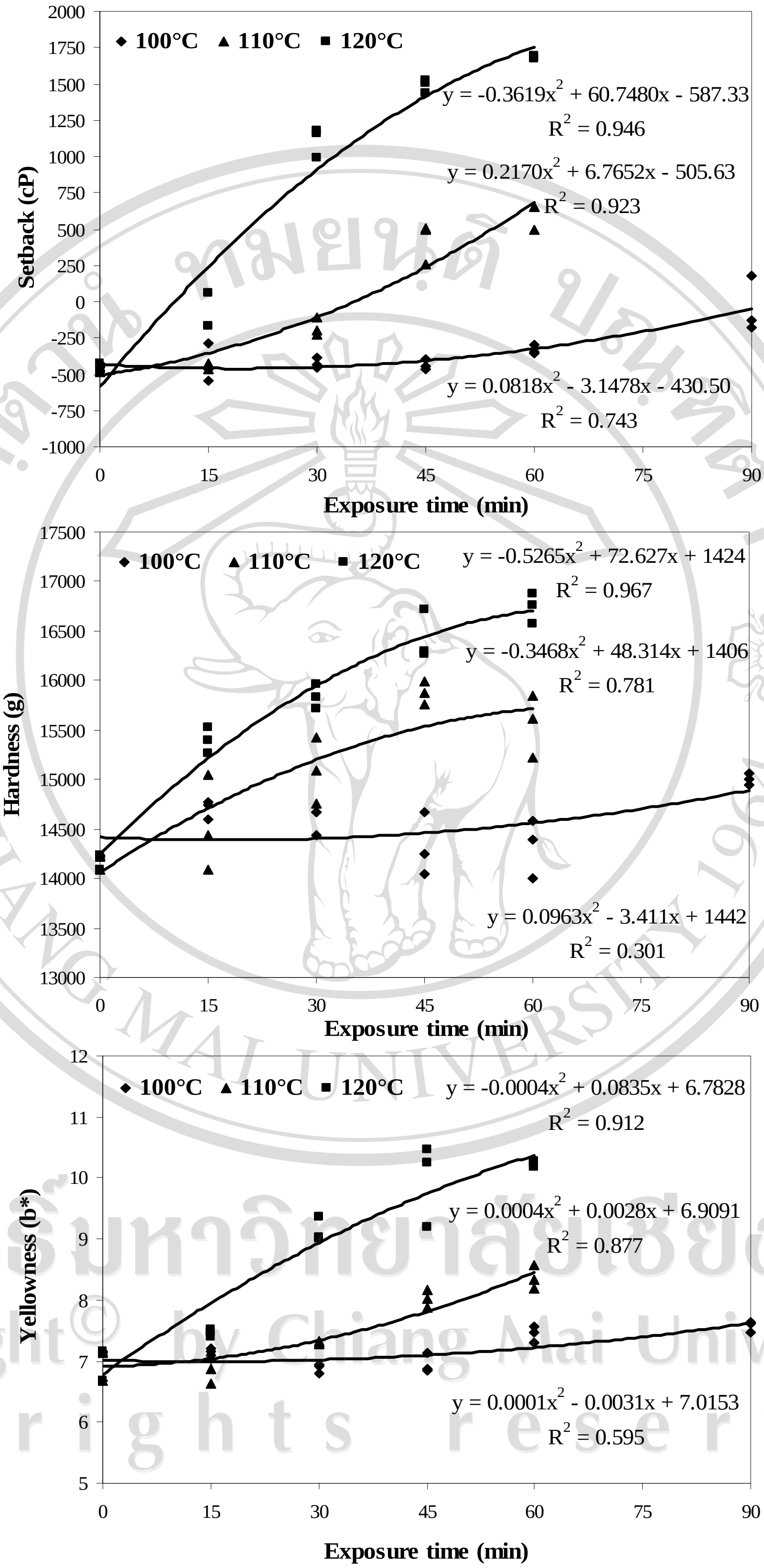

Figure 3.5 Relationship of setback, hardness and yellowness with exposure time of milled rice heating at different aging temperatures.

3.4 Conclusions

This experiment revealed that temperature and exposure duration changed pasting property, textural property and color parameters of the freshly harvested rice cv. KDML 105. The magnitude of change depended on the levels of exposure temperature and time. Higher temperature and/or longer exposure time increased hardness, springiness and decreased adhesiveness of cooked rice, and changed RVA viscosity and color parameters of fresh rice to be rice of having aged characteristics. Accelerated aging with low temperature produced rice with less yellow color and had satisfactory adhesiveness reduction when compared to that of high temperature treatments. Relationships among the rice properties were also found and setback, hardness and yellowness were the most suitable aging predictors. Thus, production of aged rice from freshly harvested rice could be done by using this information.