CHAPTER 4

Results and Discussion

4.1 Phase 1: Formulation of the optimum osmotic solution for drying intermediate moisture longan

4.1.1 Formulation of the optimum osmotic solution for intermediate moisture longan

Drying conditions were the most important parameters which affect quality of longan samples. The drying curves of IML within different formulations of osmotic solution were indicated in Fig. 4.1. It was shown the drying curves of longan samples at different formulations of osmotic solution in Fig. 4.1 (A1 – A2). The moisture contents of SGS were lower than those of SG at same drying time. It was clear in drying of samples with osmotic dehydration including SGS got the shorter drying time than the other at the same temperatures. Fig. 4.1B illustrates the variations of drying rate as a function of moisture content for different treatments. The more drying time, the lower moisture content which resulted in decreasing of drying rate. Water molecules moved faster as a result of enhanced heat transfer rate with increasing of drying temperature, which subsequently accelerated the water migration inside the product. Higher drying rate generated during the initial period of drying due to less external resistance and greater inner water migration (Qilong *et al.*, 2013). In this case, the drying time was constant with 60^{o}C, the reason of decreasing of drying rate could be because of osmotic dehydration which is a process of mass exchange, in which the solute flows into the food, while moisture is eluted from the internal food to the hypertonic solution (Ahmed *et al.*, 2016).

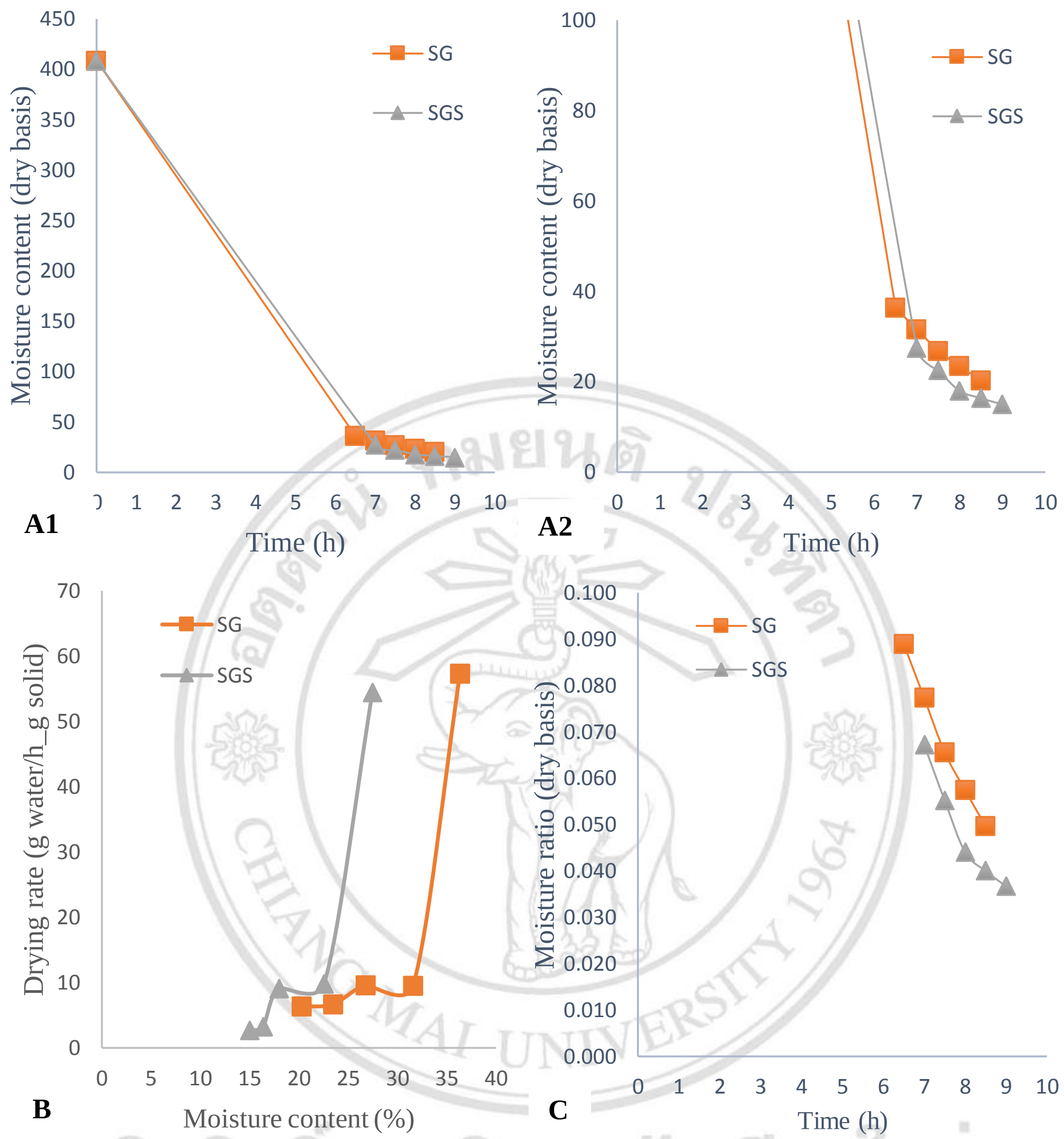

Figure 4.1 (A1 – A2) The changes in the intermediate moisture longan (IML) moisture content during hot air drying within different treatments, (B) the drying rate of IML during drying time with different conditions and (C) the effect of osmotic treatment on IML moisture ratio.

Table 4.1 Physicochemical properties of intermediate moisture longan in different treatments

Treatments	Physicochemical properties						
	a_w	**% MC**	**L*** ns	**a***	**b*** ns	**Hardness (N)**	**% DPPH inhibition***
Control	0.491 ± 0.001b	9.43 ± 0.75 c	41.51 ± 1.02	10.74 ± 1.28 b	11.91 ± 1.76	6.71 ± 1.79 b	75.76 ± 2.99 a
SG	0.602 ± 0.013 a	19.27 ± 0.74 a	41.90 ± 1.74	6.24 ± 0.49 a	11.46 ± 1.25	1.97 ± 0.69 a	42.00 ± 4.05 b
SGS	0.621 ± 0.024 a	17.82 ± 0.56 b	40.21 ± 3.75	7.39 ± 2.46 a	11.83 ± 2.13	1.83 ± 1.07 a	43.29 ± 3.17 b

a, b, c Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

SG = Sucrose and Glycerol mixture, SGS = Sucrose, Glycerol and Sorbitol mixture, control = commercial product.

Table 4.2 Acceptance scores of intermediate moisture longan in different treatments (n = 100).

Treatments	Acceptance scores				
	Overall liking ns	**Color**	**Flavor** ns	**Taste** ns	**Texture**
Control	5.4 ± 1.8	5.4 ± 1.9 b	5.4 ± 1.9	5.4 ± 1.9	4.8 ± 2.0 b
SG	5.5 ± 1.8	6.1 ± 1.7 a	5.3 ± 1.9	5.1 ± 1.9	5.5 ± 2.1 a
SGS	5.8 ± 1.9	6.3 ± 1.6 a	5.6 ± 1.9	5.4 ± 1.9	5.5 ± 2.1 a

a, b, c Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.
SG = Sucrose and Glycerol mixture, SGS = Sucrose, Glycerol and Sorbitol mixture, control = commercial product.

Moreover, it can be seen clearly in profiles of experimental moisture ratio as a function of time during drying of IML samples at different formulations of osmotic solution (Fig. 4.1C). As expected, moisture ratio decreased continuously with drying time, especially in treatment of osmotic solution containing SGS. In general, the drying temperature of 60ºC were applied to dry IML product of treatment of SGS for 8 hours compared to the other getting 7.5 hours for drying.

Physicochemical properties and acceptance scores of the intermediate moisture products were used to evaluate of qualities of IML, as shown in Table 4.1 and Table 4.2. It can be seen that the two treatments of osmotic solution gave an IML sample with low hardness as compared to control. Therefore, the osmotic dehydration could improve IML's texture. There were significantly different between water activity, moisture content and color in a* value of two treatments and control. Besides, the antioxidant capacities between two treatments were not significant different ($p > 0.05$) while there was significance of two treatments compared to control sample ($p \leq 0.05$). The color and textural liking of control were significantly lower ($p \leq 0.05$) than those of the two treatments; while the overall liking, flavor and taste scores of these products were not significant difference ($p > 0.05$) (Table 4.2). Therefore, the drying with combined osmotic solution of SGS was acceptable for the production of IML product.

4.1.2 Study on osmotic dehydration conditions for production of intermediate moisture longan

Fig. 4.2 shows the experimental data for mass variation, water loss and solid gain which were obtained during the different conditions of osmotic dehydration for the IML products. A weight reduction of the samples with osmotic dehydration time was observed for all treatments (Fig. 4.2), which is explained by the relationship of water loss and solid gain at different conditions. It can be seen clearly that the rate of water loss and solid gain were not significant difference between the three conditions. However, the rate of solid gain might be greater than the rate of water loss.

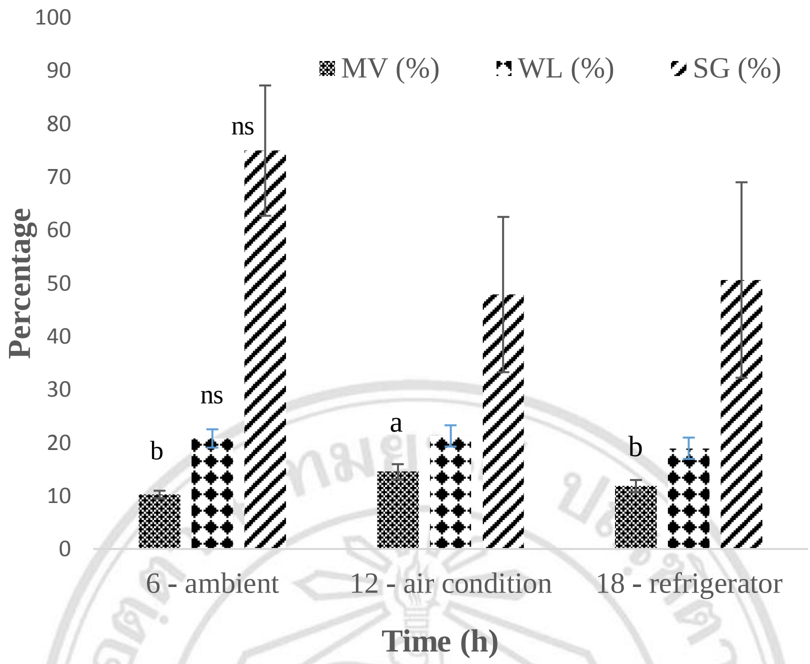

Figure 4.2 Mass variation (MV), water loss (WL) and solid gain (SG) with respect to the initial mass during the osmotic dehydration of longan in solutions containing sugar. Means with the same letter were significantly difference ($p \leq 0.05$).

It can be explained by the significant difference of mass variation for immersing at 25^{o}C for 12 hours. The permeability of small molecules through the cell membrane is allowed while restricting the transport of larger molecules such as sucrose, and then reducing the diffusion of sucrose through the cell tissue (Keila *et al.*, 2014). In this case, there were not only sucrose but also glycerol and sorbitol containing in osmotic dehydration. They might help to reduce the rate of water loss. The highest water loss was obtained when the osmotic combined solution of sucrose and glycerol (Kanitta *et al.*, 2010).

Table 4.3 Physicochemical properties of intermediate moisture longan in different methods of osmotic dehydration

Treatments	Physicochemical properties						
	a_w	% MC	L*	a* ns	b*	Hardness (N)	% DPPH inhibition ns
6h (RT)	0.689 ± 0.014 b	31.51 ± 3.33 c	41.76 ± 2.00 b	6.50 ± 2.11	22.63 ± 3.23 b	1.41 ± 0.41 a	43.74 ± 0.75
12h (25ºC)	0.602 ± 0.003 a	20.26 ± 0.89 a	44.30 ± 2.64 b	4.14 ± 1.56	20.52 ± 1.52 b	2.05 ± 1.01 b	43.29 ± 3.17
18h (4ºC)	0.705 ± 0.022 b	27.60 ± 2.27 b	36.07 ± 4.41 a	4.37 ± 0.95	13.01 ± 3.13 a	1.06 ± 0.40 a	42.51 ± 1.35

a, b, c, d Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

6h (RT) = 6 hours of immersing at room temperature, 12h (25ºC) = 12 hours of immersing at 25ºC and 18h (4ºC) = 18 hours of immersing at 4ºC.

Table 4.4 Acceptance scores of intermediate moisture longan in different methods of osmotic dehydration (n = 100)

Treatments	Acceptance scores				
	Overall liking ns	Color ns	Flavor ns	Taste ns	Texture ns
6h (RT)	5.9 ± 1.9	6.3 ± 1.7	5.6 ± 2.0	5.6 ± 2.1	5.7 ± 2.1
12h (25ºC)	6.2 ± 1.4	6.3 ± 1.5	5.9 ± 1.4	6.0 ± 1.7	6.0 ± 1.7
18h (4ºC)	5.9 ± 1.7	6.2 ± 1.7	5.6 ± 1.8	5.7 ± 2.0	5.8 ± 1.8

a, b, c, d Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

6h (RT) = 6 hours of immersing at room temperature, 12h (25ºC) = 12 hours of immersing at 25ºC and 18h (4ºC) = 18 hours of immersing at 4ºC.

Physicochemical properties of IML product were investigated and shown in Table 4.3. It can be seen that the treatment of 12 hours of immersing at 25°C illustrated an IML sample with low water activity, moisture content as compared to the others. However, the color of IML samples had change of brown color when immersing of 6 hours at the ambient temperature and 18 hours 4°C. These maybe due to the ascorbic acid oxidation occurred (Wangcharoen, 2009). Wall (2006) reported that longan fruit had the highest ascorbic acid content (60.1 mg/100 g fresh weight) among three special fruits as longan, lychee and rambutan. The antioxidant capacities of these treatments may not significant difference during processing ($p > 0.05$). In addition, the product's qualities included overall liking, color, flavor, taste and textural scores were not significant difference ($p > 0.05$) between all treatments (Table 4.4). However, the overall liking score of 12 hours of immersing at 25°C was quite higher than those of the others. From the results in Table 4.3 and 4.4, the osmotic dehydration of 12 hours immersing at 25°C might be acceptable for the production of IML.

4.2 Phase 2: Comparison of the effects of hot air drying and vacuum oven drying on the quality of intermediate moisture longan

Fig. 4.3 shows the moisture content changes of IML during hot air and vacuum drying. The moisture content decreased as the drying time lapsed, which resulted in a reduction curve. In fact, the changes in moisture content during each drying temperature were taken into consideration to be within the first falling rate period which was given by the following exponential model:

$$\frac{M - M_e}{M_o - M_e} = \exp(-k_1 t) \tag{4.1}$$

(**Source**: Orikasa *et al*., 2014)

Where M_o is the initial moisture content (d.b decimal), M_e is the equilibrium moisture content (d.b decimal), k_1 is the drying rate constant of the first falling rate drying period (h^{-1}), and t is the drying time (h).

Parameter k_1 of the samples during drying was determined by the linear regression method using the moisture content results for longan samples treated with hot air drying. The values for parameter k_1 were shown in Table 4.5. The calculated moisture content was represented as a solid line in Fig. 4.3. The measured results agreed well with the calculated results (RMSE = 0.003).

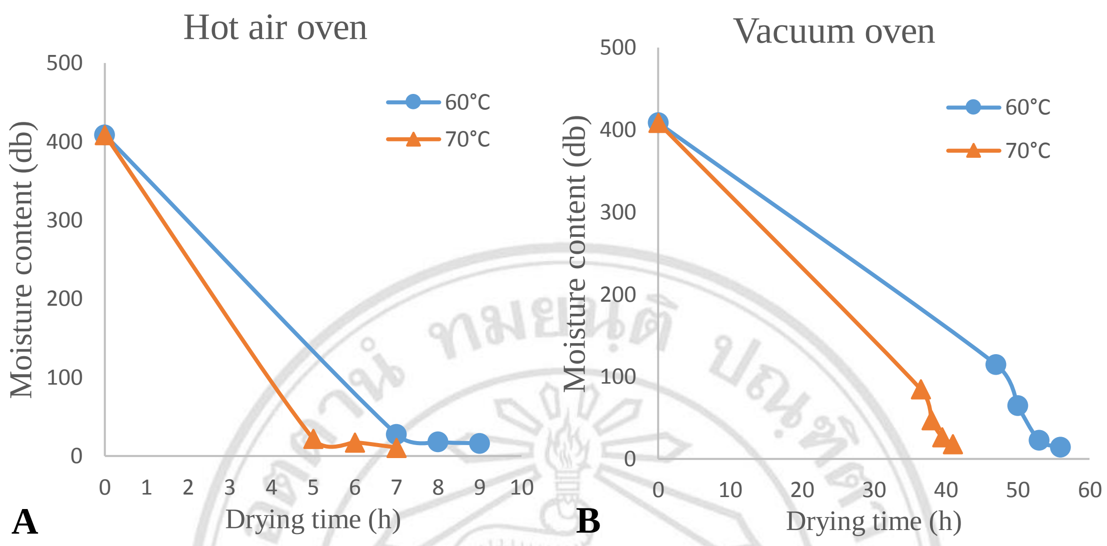

Figure 4.3 Changes in the moisture content of intermediate moisture longan during (A) hot air and (B) vacuum drying.

In the vacuum drying process, the results occurring only from the initial moisture content to approximately 50 (d.b decimal) concurred with the calculated results (RMSE = 0.137 – 0.228). The actual values from an approximate moisture content of 50 (d.b decimal) to the final stage of drying might not share any calculated values with Eq. 4.1. Therefore, the changes in moisture content from 50 (d.b decimal) until the final stage of drying must be analyzed using other equations. Page’s model has produced good fits to describe the drying of many foods and agricultural products (Orikasa *et al.*, 2014). This model is expressed as follows:

$$\frac{M - M_e}{M_o - M_e} = \exp(-k_2 t^N) \qquad (4.2)$$

(**Source**: Orikasa *et al.*, 2014)

Where k_2 is the drying rate constant of the second falling rate drying period (h^{-1}) and N is a constant. Page’s model was used to describe the behavior of longan samples during vacuum oven drying from a moisture content of 50 (d.b decimal) to the final stage of drying. Moreover, this model also was used to identify the changes in moisture content of longan sample during vacuum drying. The k_2 and N parameters in Eq. 4.2 were determined by non-linear least square method. The calculated k_2 and N values in Eq. 4.2 are determined in Table 4.5. The using of Page's model to characterize the drying process of longan fruit samples from a moisture content, which was approximately reached to 50 (d.b decimal) until the final stage of drying was supported.

From this results, it can be indicated clearly that the combination of an exponential model and Page's model could explain the changes in the moisture content from approximately 50 (d.b decimal) to the final drying stage by vacuum drying. The calculated parameter k_1 during hot air drying process was lower than that of vacuum drying process, were shown in Table 4.5. It may be due to the different temperatures of the sample body in each drying method (Orikasa *et al.*, 2014).

Table 4.5 Calculated parameters

Drying temperature (°C)	**Hot air drying** k_1	**Hot air drying** RMSE	**Vacuum drying** k_1	**Vacuum drying** RMSE	**Vacuum drying** k_2	**Vacuum drying** N	**Vacuum drying** RMSE
60°C	0.663	0.003	1.479	0.228	1.463	0.918	0.292
70°C	1.043	0.003	1.427	0.137	1.558	0.889	0.484

k_1 is the drying rate constant of the first falling rate drying period (h-1), k_2 is the drying rate constant of the second falling rate drying period (h^{-1}), RMSE = Root Mean Square Error

Table 4.6 Color parameters of intermediate moisture longan during drying.

Drying method		**ΔL***	**Δa***	**Δb***	**ΔE**
Hot air oven	60°C	8.23 ± 1.27	2.14 ± 0.82	9.41 ± 2.41	12.67 ± 1.26
	70°C	9.75 ± 3.51	4.03 ± 1.68	12.18 ± 1.75	16.15 ± 2.22
Vacuum oven	60°C	10.85 ± 2.05	1.15 ± 0.51	8.22 ± 1.88	13.56 ± 2.27
	70°C	10.62 ± 1.53	3.14 ± 0.51	11.18 ± 3.21	15.66 ± 2.50

Table 4.7 Effect of two drying methods on the physicochemical and sensorial properties of intermediate moisture longan

Properties	**Parameters**	**Drying method (A)**	**Drying temperature (B)**	**A * B**
	L*	**ns**	**ns**	**ns**
	a*	*	*	**ns**
Physicochemical	b*	**ns**	*	**ns**
	Hardness	*	*	*
	% DPPH	*	*	*
	Overall liking	**ns**	*	**ns**
	Color	**ns**	*	*
Sensorial	Flavor	**ns**	**ns**	**ns**
	Taste	**ns**	**ns**	**ns**
	Texture	*	*	**ns**

ns is not significantly different ($p > 0.05$). * is significantly different ($p \leq 0.05$).

The total color change (ΔE) in the longan samples was determined using (L*, a*, b*) values to evaluate the color change during drying process. A larger ΔE value, a larger color change represents from the fresh longan reference color. Table 4.6 shows the color parameter for fresh and IML during drying process. The sensory evaluation level was described as "very much" when the total color change (ΔE) of the samples at all temperatures and for each way of drying process was higher than 12 (Orikasa *et al.*, 2014). The color change (Δa*) of samples after vacuum drying at each temperature level was significantly lower than that of after hot air drying ($p \leq 0.05$) (Table 4.6). Orikasa *et al.* (2014) reported that color change of the kiwifruit samples also significant difference between after vacuum and hot air drying. It can be explained that this change could be accounted for a non – enzymatic browning reaction (or Maillard reaction) (Orikasa *et al.*, 2014) because of the change in free sugar content and free amino acid content in longan fruits during drying (Contis *et al*, 1998). The amount of free sugar in fresh of longan is presented in the order of glucose, maltose, sucrose, xylose and fructose while some of these amino acids, such as proline and leucine, significantly decreased in the amount after drying (Contis *et al.*, 1998). Moreover, this reaction might be inhibited by lower temperature (Honma and Murata, 2011). Basically the sample temperature during vacuum processing was lower than that during hot air processing. Therefore, a* values of longan sample, which were changed by Maillard reaction was inhibited appreciably during vacuum drying.

Physicochemical and sensorial properties of IML products dried from hot air and vacuum drying processes were investigated and shown in Table 4.7, 4.8 and 4.9. There were significantly different ($p \leq 0.05$) effect of drying methods and drying temperatures on a* values, texture and antioxidant capacities of IML products (Table 4.7 and 4.8). It can be seen clearly that a* value increased with the increasing of temperature at each drying method and had change to brown color due to the non – enzymatic browning reaction (Orikasa *et al.*, 2014). The antioxidant capacities of IML product also increased with increasing temperature at each drying method. Therefore, the antioxidant capacities at high temperature level were greater than that at low temperature level for each drying process. Lopez *et al.* (2013) reported that the radical scavenging activity in dried golden berry indicated higher antioxidant activity at higher temperatures than lower temperatures. Besides that, the product's qualities included flavor, taste scores were not significant difference ($p > 0.05$) while their overall liking, color and textural scores were significant difference ($p \leq 0.05$) between treatments (Table 4.7 and 4.9).

Table 4.8 Physicochemical properties of intermediate moisture longan between two drying methods

Drying methods		Physicochemical properties				
		L*^{ns}	a*	b*	Hardness (N)*	% DPPH inhibition *
Hot air oven	60°C	36.54 ± 1.82	1.97 ± 0.59 b	10.26 ± 1.98 b	3.58 ± 0.79 a	43.29 ± 3.17 a
	70°C	38.06 ± 3.04	3.87 ± 1.57 d	13.03 ± 1.93 d	5.79 ± 1.71 b	55.53 ± 2.03 c
Vacuum oven	60°C	39.16 ± 1.94	0.99 ± 0.57 a	9.07 ± 2.21 a	5.91 ± 1.89 c	50.11 ± 1.71 b
	70°C	38.93 ± 1.79	2.97 ± 0.47 c	12.03 ± 2.80 c	5.93 ± 0.79 d	55.78 ± 4.60 d

a, b, c, d Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

Table 4.9 Acceptance scores of intermediate moisture longan between two drying methods (n = 100)

Drying methods		Acceptance scores				
		Overall liking *	Color *	Flavor ^{ns}	Taste ^{ns}	Texture *
Hot air oven	60°C	6.7 ± 1.3 a	6.6 ± 1.6 a	6.4 ± 1.7	6.6 ± 1.7	6.7 ± 1.7 a
	70°C	6.0 ± 1.4 c	5.9 ± 1.4 c	6.4 ± 1.7	6.5 ± 1.7	5.9 ± 1.8 c
Vacuum oven	60°C	6.3 ± 1.4 b	6.3 ± 1.5 b	6.2 ± 1.7	6.3 ± 1.7	6.1 ± 1.6 b
	70°C	6.0 ± 1.4 c	6.3 ± 1.5 b	6.2 ± 1.6	6.2 ± 1.6	5.8 ± 1.8 d

a, b, c, d Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

4.3 Phase 3: Determination of the qualities of intermediate moisture longan product using fresh longan compare with frozen longan

Fig. 4.4 shows the drying curves of longan samples using different kinds of raw material. It was clear in drying of samples from frozen longan got the shorter drying time than from the fresh longan at the same temperatures. It can be seen clearly in profiles of experimental moisture ratio as a function of time during drying of IML samples at different treatments. As expected, moisture ratio decreased continuously with drying time, especially in treatment drying from frozen longan which showed the trend of decreasing moisture ratio was so quickly.

The quality of IML product were evaluated and shown in Table 4.10 and 4.11. It can be observed that using fresh long gave an IML sample with low hardness and golden yellow as compared to the one using frozen longan. However, Krit *et al.* (2015) reported that the hardness of normal dried longan dried by hot air oven was 9.76 ± 1.56 (N). It can be compared with IML sample in this study, although there were significant effects on hardness properties of longan samples, their textures were softer than the normal dried longan. Moreover, there is significant difference between antioxidant capacities of IML from fresh and frozen longan ($p \leq 0.05$). The antioxidant capacities at high temperature level (fresh longan) were greater than that at low temperature (frozen longan). Lopez *et al.* (2013) studied the radical scavenging activity showed higher antioxidant activity at higher temperatures than lower temperature. In general, IML product from fresh longan and frozen longan were not significantly different ($p > 0.05$) in physicochemical properties and sensorial scores of IML samples (Table 4.10 and 4.11). Therefore, either using fresh longan or frozen longan for production of IML products was acceptable to consumers.

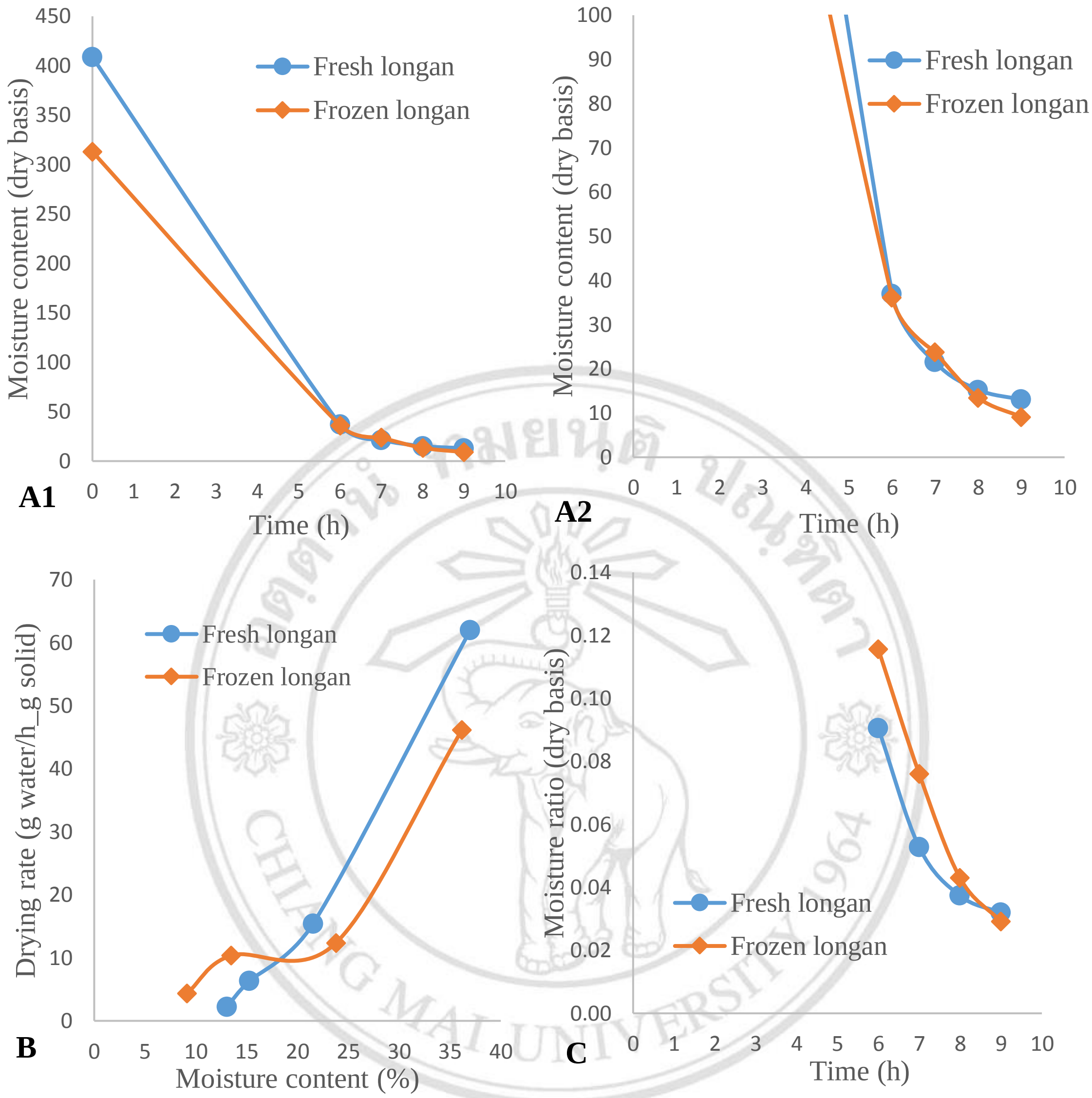

Figure 4.4 (A1 – A2) The changes in the intermediate moisture longan (IML) moisture content during hot air drying within different treatments, (B) the drying rate of IML during drying time with different conditions and (C) the effect of osmotic treatment on IML moisture ratio.

Table 4.10 Physicochemical properties of intermediate moisture longan in different raw materials.

Treatments	Physicochemical properties						
	a_w ns	MC ns	L* ns	a* ns	b*	Hardness (N)	% DPPH inhibition*
From fresh	0.609 ± 0.017	19.22 ± 2.78	40.77 ± 5.38	4.74 ± 1.39	20.46 ± 1.82 a	2.21 ± 1.24 a	43.29 ± 3.17 a
From frozen	0.618 ± 0.025	23.68 ± 6.26	36.58 ± 2.93	4.51 ± 1.30	11.76 ± 0.94 b	3.88 ± 1.41 b	32.70 ± 2.68 b

a, b Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

Table 4.11 Acceptance scores of intermediate moisture longan in different raw materials (n = 100).

Treatments	Acceptance scores				
	Overall liking ns	Color ns	Flavor ns	Taste ns	Texture ns
From fresh	6.0 ± 1.5	6.2 ± 1.7	5.8 ± 1.7	6.1 ± 1.7	5.8 ± 1.6
From frozen	6.2 ± 1.6	6.2 ± 1.8	5.9 ± 1.8	6.1 ± 1.8	5.9 ± 1.7

a, b Means in same column with different letters are significantly different ($p \leq 0.05$). ns is not significantly different.

4.4 Shelf – life evaluation of intermediate moisture longan

4.4.1 Quality changes of intermediate moisture longan during storage time

To estimate the quality changes of IML products during storage time, the IML products were then kept in 3 different kinds of package which are aluminum foil laminated with plastic bag packed with nitrogen (Al bag with nitrogen), aluminum foil laminated with plastic bag packed without nitrogen (Al bag without nitrogen) and clear plastic bag and stored at the different temperatures (4, 25, 35 and 45^{o}C) during 6 months. The change in physicochemical properties of food occur during storage period. The temperatures of storage and packaging types are the major factors which influence the physical, chemical and sensory properties of IML.

The water activity and moisture content of the IML were recorded in Table 4.13 - 4.18. According to ANOVA results, the temperature of storage and packaging types were significant effectives on water activity and moisture content of longan samples ($p \leq 0.05$). The storage time affected on the samples' water activities ($p \leq 0.05$) while it might not influence on moisture content of samples ($p > 0.05$). The water activity and moisture content of samples packed with three types of plastic bags and stored at 35^{o}C, 45^{o}C showed the decreasing trend during 16 weeks due to the phenomenon of evaporation occurred inside these packages (Fig. 4.5), especially in decreasing slowly with aluminum laminated plastic bag with nitrogen which can retained their moisture contents. This package is known to have good moisture barrier properties, exceptionally with nitrogen (Sudhanshu *et al*., 2009). In general, the effect of interaction between temperatures of storage, packaging types on the water activity and moisture content of IML was significant difference ($p \leq 0.05$) (Table 4.12). Panwar *et al*. (2013) studied that the water activity and moisture content of intermediate moisture aonla segments, which were packed in low – density polyethylene bags and stored at room temperature, decreased significantly during six months storage period.

Table 4.12 ANOVA for water activities and moisture contents of intermediate moisture longan during storage.

Source of variation	df	Mean square			
		Water activity	P - value	Moisture content	P - value
Temperature of storage (TS)	3	0.200	0.000	2012.11	0.000
Packaging types (PT)	2	0.011	0.002	416.68	0.000
Storage period (SP)	12	0.014	0.000	356.54	0.000
Effect of (TS x PT)	6	0.079	0.000	149.54	0.000
Error		0.002		17.44	

Table 4.13 Water activities of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45^{o}C).

Storage period (weeks)	Al bag with nitrogen			
	4^{o}C	25^{o}C	35^{o}C	45^{o}C
0	0.600 ± 0.020	0.600 ± 0.020	0.600 ± 0.020	0.600 ± 0.020
2	0.604 ± 0.038	0.612 ± 0.007	0.653 ± 0.038	0.656 ± 0.004
4	0.601 ± 0.042	0.627 ± 0.008	0.648 ± 0.033	0.653 ± 0.036
6	0.614 ± 0.017	0.628 ± 0.018	0.622 ± 0.062	0.640 ± 0.020
8	0.616 ± 0.010	0.636 ± 0.030	0.631 ± 0.021	0.636 ± 0.019
10	0.619 ± 0.021	0.636 ± 0.005	0.633 ± 0.014	0.635 ± 0.022
12	0.621 ± 0.014	0.647 ± 0.010	0.628 ± 0.013	0.630 ± 0.008
14	0.622 ± 0.018	0.648 ± 0.031	0.630 ± 0.009	0.628 ± 0.014
16	0.622 ± 0.010	0.666 ± 0.041	0.630 ± 0.017	0.606 ± 0.043
18	0.626 ± 0.009	0.660 ± 0.038	-	-
20	0.626 ± 0.013	0.643 ± 0.017	-	-
22	0.626 ± 0.012	0.641 ± 0.005	-	-
24	0.620 ± 0.039	0.684 ± 0.029	-	-

- no measurement because shelf – life was ended.

Table 4.14 Water activities of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45°C).

Storage period (weeks)	Al bag without nitrogen			
	4°C	25°C	35°C	45°C
0	0.600 ± 0.020	0.600 ± 0.020	0.600 ± 0.020	0.600 ± 0.020
2	0.663 ± 0.030	0.634 ± 0.024	0.625 ± 0.070	0.610 ± 0.009
4	0.665 ± 0.025	0.655 ± 0.035	0.629 ± 0.074	0.607 ± 0.039
6	0.668 ± 0.047	0.661 ± 0.038	0.630 ± 0.031	0.590 ± 0.055
8	0.684 ± 0.025	0.671 ± 0.006	0.627 ± 0.017	0.582 ± 0.034
10	0.689 ± 0.011	0.691 ± 0.015	0.622 ± 0.016	0.552 ± 0.007
12	0.692 ± 0.017	0.701 ± 0.012	0.619 ± 0.009	0.550 ± 0.009
14	0.689 ± 0.012	0.719 ± 0.040	0.583 ± 0.009	0.526 ± 0.006
16	0.710 ± 0.006	0.732 ± 0.055	0.582 ± 0.010	0.511 ± 0.019
18	0.714 ± 0.031	0.714 ± 0.006	-	-
20	0.720 ± 0.040	0.716 ± 0.008	-	-
22	0.728 ± 0.017	0.715 ± 0.015	-	-
24	0.732 ± 0.039	0.715 ± 0.004	-	-

\- no measurement because shelf – life was ended.

Table 4.15 Water activities of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Clear plastic bag			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	0.600 ± 0.020	0.600 ± 0.020	0.600 ± 0.020	0.600 ± 0.020
2	0.635 ± 0.023	0.656 ± 0.028	0.645 ± 0.021	0.617 ± 0.038
4	0.665 ± 0.037	0.661 ± 0.040	0.641 ± 0.017	0.579 ± 0.004
6	0.666 ± 0.009	0.674 ± 0.026	0.639 ± 0.020	0.573 ± 0.038
8	0.670 ± 0.008	0.681 ± 0.011	0.603 ± 0.008	0.570 ± 0.044
10	0.677 ± 0.009	0.697 ± 0.009	0.603 ± 0.038	0.526 ± 0.008
12	0.696 ± 0.011	0.703 ± 0.007	0.589 ± 0.004	0.523 ± 0.037
14	0.699 ± 0.012	0.709 ± 0.057	0.549 ± 0.018	0.409 ± 0.007
16	0.705 ± 0.036	0.724 ± 0.049	0.533 ± 0.004	0.360 ± 0.013
18	0.703 ± 0.062	0.718 ± 0.016	-	-
20	0.715 ± 0.005	0.717 ± 0.018	-	-
22	0.710 ± 0.069	0.720 ± 0.009	-	-
24	0.724 ± 0.033	0.726 ± 0.050	-	-

- no measurement because shelf – life was ended.

Table 4.16 Moisture contents (%) of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	**Al bag with nitrogen**			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	23.58 ± 1.68	23.58 ± 1.68	23.58 ± 1.68	23.58 ± 1.68
2	27.46 ± 3.78	23.04 ± 2.36	26.52 ± 1.60	32.77 ± 6.35
4	27.47 ± 3.36	25.06 ± 3.07	24.71 ± 6.40	28.15 ± 0.82
6	27.60 ± 3.93	25.76 ± 2.95	23.30 ± 0.52	27.74 ± 1.42
8	28.91 ± 3.05	27.06 ± 1.42	22.33 ± 2.22	24.52 ± 2.78
10	29.51 ± 2.03	32.37 ± 1.58	21.30 ± 0.95	23.26 ± 1.58
12	28.21 ± 1.11	32.82 ± 2.02	20.23 ± 4.10	22.60 ± 2.69
14	27.29 ± 0.84	34.63 ± 1.87	19.46 ± 5.67	22.00 ± 1.36
16	30.99 ± 1.27	36.54 ± 2.04	18.57 ± 2.59	19.81 ± 7.80
18	31.53 ± 4.10	37.16 ± 1.59	-	-
20	31.85 ± 2.47	37.28 ± 3.97	-	-
22	32.30 ± 0.53	38.78 ± 0.45	-	-
24	32.32 ± 1.39	39.05 ± 1.22	-	-

- no measurement because shelf – life was ended.

Table 4.17 Moisture contents (%) of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag without nitrogen			
	4ºC	25ºC	35ºC	45ºC
0	23.58 ± 1.68	23.58 ± 1.68	23.58 ± 1.68	23.58 ± 1.68
2	27.08 ± 6.44	23.15 ± 4.08	24.63 ± 3.43	24.25 ± 1.79
4	27.66 ± 2.49	25.15 ± 4.47	23.61 ± 5.57	23.15 ± 1.83
6	28.71 ± 4.73	25.26 ± 1.63	23.46 ± 0.54	19.72 ± 4.10
8	29.98 ± 8.47	26.55 ± 4.20	22.45 ± 1.51	19.90 ± 0.53
10	30.57 ± 1.41	29.12 ± 1.05	22.40 ± 0.93	19.89 ± 0.53
12	31.10 ± 0.86	29.91 ± 1.55	21.64 ± 0.71	18.60 ± 3.46
14	31.43 ± 1.43	33.03 ± 1.42	20.32 ± 1.57	18.32 ± 6.95
16	31.74 ± 1.40	34.54 ± 1.60	19.98 ± 4.50	18.10 ± 0.84
18	32.46 ± 2.70	34.56 ± 2.24	-	-
20	32.58 ± 0.54	38.83 ± 1.39	-	-
22	32.93 ± 0.82	39.51 ± 1.48	-	-
24	33.25 ± 1.56	40.35 ± 4.13	-	-

- no measurement because shelf – life was ended.

Table 4.18 Moisture contents (%) of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Clear plastic bag			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	23.58 ± 1.68	23.58 ± 1.68	23.58 ± 1.68	23.58 ± 1.68
2	25.88 ± 3.03	24.37 ± 1.59	25.84 ± 3.28	22.93 ± 2.02
4	26.67 ± 2.11	24.36 ± 1.68	23.15 ± 2.33	21.33 ± 1.55
6	26.38 ± 3.73	25.78 ± 2.67	21.17 ± 2.83	19.40 ± 2.00
8	26.28 ± 0.86	27.10 ± 0.82	20.40 ± 1.35	19.23 ± 1.05
10	26.62 ± 1.19	29.18 ± 1.10	17.80 ± 3.35	15.51 ± 0.40
12	28.01 ± 3.06	29.22 ± 2.63	17.42 ± 0.82	14.01 ± 0.38
14	29.16 ± 1.57	31.25 ± 0.80	17.24 ± 1.33	9.04 ± 0.31
16	29.91 ± 0.32	31.93 ± 2.14	15.97 ± 0.45	8.75 ± 0.87
18	30.31 ± 2.88	33.76 ± 2.45	-	-
20	31.32 ± 0.92	35.44 ± 4.26	-	-
22	31.98 ± 1.54	40.95 ± 1.02	-	-
24	32.14 ± 2.09	44.07 ± 13.5	-	-

- no measurement because shelf – life was ended.

Figure 4.5 The intermediate moisture longan stored with clear plastic bag at 45°C for 16 weeks.

According to Microbiological Guidelines for Food (2014) the satisfactory total number of bacteria able to grow in an aerobic environment in moderate temperature, "Aerobic colony count (ACC)" for sweet foods is lower than 10^4 cfu/g products. The colonies of total bacterial, yeast and mold counts were found in Table 4.19, 4.20 and 4.21. There was an increase in total bacterial count, yeast and mold count of IML packed into three different packing materials during storage period at 4°C and 25°C. Moreover, there had no microorganism growth until 16th week, 12th week and 8th week for IML products packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. Then the shelf life of IML products packed in three different packing materials and stored at 35°C and 45°C were ended from 20th week as a results of sensory evaluation (acceptance scores less than 5.0), and then the microbial analyze was skipped. At 24th week (or 6 months), the results of survival microorganisms in IML samples, which packed in Al bag with nitrogen and stored at 4°C and 25°C, have the lower number in total count of bacteria than the standard (10^4 cfu/g). The results of survival microorganisms in IML samples, which packed in Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, increased at 24th week, from 16th week to 24th week and from 12th week to 24th week, respectively. They had the lower number in TBC than the standard (10^4 cfu/g) when they were stored at 4°C and 25°C. These show that combination of osmotic dehydration, drying method with packing conditions improved the microbial stability and controlled the growth of microbes. Sudhanshu *et al.* (2009) reported that total bacterial and yeast and mold counts can be detected in intermediate moisture pineapple (a_w = 0.82) packed in high density polyethylene bags and stored at ambient temperature with 2 x 10^2 cfu/g at 20 days of storage. Furthermore, Chaturvedi *et al*. (2013) studied that the total bacterial counts and total mould counts can be found in intermediate moisture carrot (a_w = 0.6) packed in polyethylene bags and stored at ambient temperature with 2.1 x 10^2 cfu/g and 2.08 x 10^2 cfu/g, respectively. Besides that, it can be seen clearly that yeast and mold counts were not detected during 6 months. These may be because of the combination of osmotic dehydration, drying method and packing conditions that reduced water activity in a range of 0.600 – 0.730 during 6 months of storage, especially IML products were packed in Al bag with nitrogen. The water activity is an important parameter which can affect on microbial count and totally important for shelf – life of intermediate moisture products (Ahmed *et al.*, 2016). Homhuan (2013) reported that there was not detected yeast and mold in dried longan, which was produced by using osmotic dehydration and packed in aluminum foil laminated plastic bags with nitrogen. Microbiological Guidelines for Food (2014) *E. coli* is a commonly used faecal indicator organism. Its presence in food generally indicates direct or indirect faecal contamination. Substantial number of *E. coli* in food recommends a general lack of cleanliness in handling and improper storage. The satisfactory total number of *E. coli* able to grow for food is lower than 20 cfu/g. In this study, it revealed that product was safe for human consumption since *E. coli* was absent.

Table 4.19, 4.20 and 4.21 show that the microbial counts were detected at 24th week for IML packed in Al bag with nitrogen, at 16th week for IML packed in Al bag without nitrogen and at 12th week for IML packed in clear plastic bag during 6 months of storage. Therefore, when IML products were packed in Al bag with nitrogen, the microbial safety was confirmed, followed by IML products packed in Al bag without nitrogen and clear plastic bag. Finally, IML products packed in Al bag with nitrogen could be kept longer than others.

Table 4.19 Microbiological analysis of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45^{o}C).

	Storage period (weeks)	Al bag with nitrogen			
		4^{o}C	**25^{o}C**	**35^{o}C**	**45^{o}C**
Total bacterial count (cfu/g)	0	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	4	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	8	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	12	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	16	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	20	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	-	-
	24	6.5 x 10	6.5 x 10	-	-
Yeast and mold count (cfu/g)	0	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	4	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	8	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	12	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	16	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	20	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	-	-
	24	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	-	-

\- no measurement because shelf – life was ended.

Table 4.20 Microbiological analysis of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

	Storage period (weeks)	Al bag without nitrogen			
		4ºC	25ºC	35ºC	45ºC
Total bacterial count (cfu/g)	0	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	4	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	8	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	12	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	16	5.5 x 10	2.5 x 10	2.0 x 10	2.0 x 10
	20	5.5 x 10	6.0 x 10	-	-
	24	7.5 x 10	8.5 x 10	-	-
Yeast and mold count (cfu/g)	0	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	4	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	8	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	12	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	16	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}	< 2.5×10^{-1}
	20	< 2.5×10^{-1}	< 2.5×10^{-1}	-	-
	24	< 2.5×10^{-1}	< 2.5×10^{-1}	-	-

- no measurement because shelf – life was ended.

Table 4.21 Microbiological analysis of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45°C).

	Storage period (weeks)	Clear plastic bag			
		4°C	**25°C**	**35°C**	**45°C**
Total bacterial count (cfu/g)	0	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	4	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	8	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	12	4.0 x 10	4.0 x 10	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	16	3.0 x 10	2.0 x 10	4.5 x 10	5.0 x 10
	20	4.5 x 10	3.0 x 10	-	-
	24	5.0 x 10	5.5 x 10	-	-
Yeast and mold count (cfu/g)	0	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	4	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	8	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	12	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	16	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$
	20	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	-	-
	24	$< 2.5 \times 10^{-1}$	$< 2.5 \times 10^{-1}$	-	-

\- no measurement because shelf – life was ended.

Color influencing the consumer acceptability is a very essential quality characteristic of fruit and vegetable products (Muzaffar and Kumar, 2016). Color changes of IML samples during storage using different packaging types at different temperatures can be seen clearly in Table 4.23 – 4.31. During storage, L* and b* values decreased (darker and blue color) while a* value increased (red color). The ANOVA results showed that temperatures of storage, packaging types within storage period significantly ($p \leq 0.05$) affected on the color values of IML (Table 4.22). Browning reactions in this study were non – enzymatic browning reactions which might be Maillard reaction and ascorbic acid oxidation due to longan contained reducing sugar, amino acid and ascorbic acid. Wangcharoen (2009) studied that Maillard reaction could occur between carbonyl groups and amino compounds, while ascorbic acid oxidation might be the thermal decomposition of ascorbic acid. Wall (2006) reported that longan fruit had the highest ascorbic acid content (60.1 mg/100 g fresh weight) among three special fruits as longan, lychee and rambutan.

Browning reaction occurs in peeled longan due to polyphenol oxidase (PPO) action. The enzyme is located in plastids and cytoplasm inside the cell and phenolic substrate are located in vacuole, to form brown polymers (Sudhanshu *et al.*, 2009, Yifen *et al.*, 2015). After peeling and keeping longan flesh at the ambient temperature, the enzyme and substrate contact together in presence of oxygen, results in formation of *quinones* – brown polymers. Moreover, drying condition including temperature and time also affect on the color of longan. Therefore, these reactions can affect on color, flavor and odor of IML after drying. Citric acid was used in the experiment and dipped in sugar solution which reduce *quinones* back to their congenital phenols before they carry out further reaction to form pigments, resulting in preventing the browning reaction of final product (Nadeem *et al.*, 2013).

From results of color analysis during 6 months of storage, the color of IML products did not changed completely during storage period when they were packed in Al bag with nitrogen at 4^{o}C, followed by 25^{o}C compared with IML packed in Al bag without nitrogen and clear plastic bag (Fig. A – 8 to Fig. A – 19). Therefore, it can be seen clearly that IML packed in Al bag with nitrogen could be kept longer than the others. In fact, there were significantly different ($p \leq 0.05$) between IML products packed in three packing materials (Table 4.22).

Table 4.22 ANOVA for color analysis of intermediate moisture longan during storage.

Source of variation	df	Mean square					
		L*	P - value	a*	P - value	b*	P - value
Temperature of storage (TS)	3	3150.70	0.000	14.65	0.000	1255.84	0.000
Packaging types (PT)	2	1647.65	0.000	23.45	0.000	137.37	0.000
Storage period (SP)	12	842.88	0.000	101.71	0.000	291.11	0.000
Effect of (TS x PT)	6	550.72	0.000	6.37	0.000	42.47	0.000
Error		4.60		1.53		3.01	

Table 4.23 L* value changes of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag with nitrogen			
	4ºC	25ºC	35ºC	45ºC
0	40.60 ± 1.73	40.60 ± 1.73	40.60 ± 1.73	40.60 ± 1.73
2	34.76 ± 1.63	29.39 ± 2.60	26.27 ± 1.32	22.60 ± 0.96
4	33.45 ± 2.63	29.19 ± 0.83	26.20 ± 0.78	22.21 ± 0.81
6	33.14 ± 2.10	28.72 ± 1.71	26.03 ± 3.06	21.84 ± 2.01
8	33.01 ± 1.06	28.38 ± 1.58	25.66 ± 1.43	21.45 ± 0.95
10	32.25 ± 1.61	28.53 ± 0.82	24.02 ± 1.73	21.08 ± 1.81
12	32.42 ± 0.85	28.55 ± 1.35	23.15 ± 2.53	20.64 ± 0.71
14	32.64 ± 0.32	28.45 ± 0.40	19.71 ± 1.17	19.70 ± 0.86
16	31.92 ± 0.97	27.99 ± 1.53	19.55 ± 0.89	19.54 ± 1.00
18	29.56 ± 1.67	27.88 ± 1.55	-	-
20	28.90 ± 2.57	27.52 ± 1.66	-	-
22	27.26 ± 2.69	26.07 ± 1.08	-	-
24	26.89 ± 1.78	22.39 ± 3.50	-	-

- no measurement because shelf – life was ended

Table 4.24 L* value changes of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag without nitrogen			
	4ºC	25ºC	35ºC	45ºC
0	40.60 ± 1.73	40.60 ± 1.73	40.60 ± 1.73	40.60 ± 1.73
2	34.10 ± 0.88	32.41 ± 2.38	31.42 ± 1.20	24.02 ± 1.82
4	33.56 ± 2.06	33.41 ± 0.76	31.40 ± 0.92	23.85 ± 0.58
6	33.23 ± 2.10	32.91 ± 0.96	30.74 ± 4.15	23.76 ± 1.72
8	34.81 ± 2.03	31.40 ± 0.80	29.26 ± 0.77	23.54 ± 1.37
10	34.62 ± 1.94	31.06 ± 0.49	28.38 ± 2.74	23.37 ± 1.20
12	34.91 ± 1.05	30.80 ± 1.33	27.84 ± 1.91	23.02 ± 1.65
14	32.47 ± 0.91	30.63 ± 0.74	25.22 ± 1.94	22.14 ± 0.95
16	32.09 ± 1.36	30.57 ± 1.15	23.85 ± 1.76	20.90 ± 1.48
18	28.78 ± 1.72	30.20 ± 0.83	-	-
20	28.60 ± 3.63	28.77 ± 1.36	-	-
22	27.28 ± 1.86	27.78 ± 0.83	-	-
24	27.01 ± 1.22	25.52 ± 1.49	-	-

- no measurement because shelf – life was ended.

Table 4.25 L* value changes of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Clear plastic bag			
	4ºC	25ºC	35ºC	45ºC
0	40.60 ± 1.73	40.60 ± 1.73	40.60 ± 1.73	40.60 ± 1.73
2	34.85 ± 1.40	29.21 ± 1.99	26.68 ± 0.91	28.72 ± 0.22
4	34.65 ± 1.54	29.08 ± 0.25	26.60 ± 1.76	27.25 ± 0.85
6	35.54 ± 2.41	29.04 ± 1.11	26.53 ± 2.12	24.57 ± 1.45
8	32.70 ± 2.77	29.22 ± 1.21	25.66 ± 0.98	23.30 ± 2.02
10	32.73 ± 1.02	29.91 ± 1.28	25.56 ± 2.53	23.10 ± 0.69
12	32.67 ± 1.47	29.16 ± 1.01	24.66 ± 1.82	22.66 ± 2.45
14	32.70 ± 0.61	29.91 ± 1.17	23.51 ± 1.17	22.44 ± 0.91
16	32.62 ± 1.96	29.80 ± 1.65	23.35 ± 1.00	21.83 ± 0.97
18	29.53 ± 2.30	28.51 ± 1.99	-	-
20	28.89 ± 2.26	27.16 ± 1.12	-	-
22	27.06 ± 2.66	26.68 ± 1.28	-	-
24	26.45 ± 2.21	23.32 ± 1.93	-	-

- no measurement because shelf – life was ended.

Table 4.26 a* value changes of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period	Al bag with nitrogen			
(weeks)	4ºC	25ºC	35ºC	45ºC
0	3.85 ± 2.39	3.85 ± 2.39	3.85 ± 2.39	3.85 ± 2.39
2	4.12 ± 0.88	4.14 ± 1.13	3.87 ± 0.89	2.98 ± 0.25
4	5.01 ± 1.57	4.54 ± 0.74	4.81 ± 1.74	4.83 ± 0.45
6	5.44 ± 0.82	5.02 ± 0.59	5.62 ± 2.03	4.86 ± 1.09
8	5.06 ± 0.82	5.28 ± 0.37	6.28 ± 1.15	5.94 ± 0.47
10	4.81 ± 1.09	5.53 ± 0.86	6.99 ± 2.01	6.12 ± 0.69
12	5.25 ± 1.03	6.58 ± 0.75	7.24 ± 0.90	6.40 ± 0.77
14	5.19 ± 1.51	6.63 ± 1.02	7.69 ± 1.13	6.77 ± 0.79
16	6.24 ± 1.27	7.00 ± 0.27	7.51 ± 1.07	6.96 ± 0.63
18	8.33 ± 0.92	7.96 ± 1.10	-	-
20	8.27 ± 0.98	8.60 ± 0.62	-	-
22	8.60 ± 0.75	8.67 ± 0.65	-	-
24	8.72 ± 1.01	9.02 ± 0.71	-	-

- no measurement because shelf – life was ended.

Table 4.27 a* value changes of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	**Al bag without nitrogen**			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	3.85 ± 2.39	3.85 ± 2.39	3.85 ± 2.39	3.85 ± 2.39
2	4.02 ± 0.41	3.12 ± 1.28	4.03 ± 0.55	4.54 ± 0.23
4	5.55 ± 1.62	4.87 ± 0.71	5.09 ± 0.53	4.59 ± 0.65
6	5.23 ± 0.83	4.57 ± 2.01	6.26 ± 1.31	5.28 ± 0.87
8	5.32 ± 0.98	4.71 ± 1.08	6.45 ± 0.95	5.58 ± 0.85
10	4.97 ± 0.98	5.53 ± 1.15	6.17 ± 1.07	5.50 ± 1.06
12	4.14 ± 1.58	6.63 ± 0.28	6.53 ± 1.75	6.00 ± 1.59
14	5.43 ± 0.72	7.98 ± 0.59	6.30 ± 0.93	5.64 ± 0.48
16	5.36 ± 1.33	7.85 ± 0.89	6.68 ± 1.25	6.54 ± 0.89
18	6.08 ± 0.72	8.95 ± 0.97	-	-
20	7.24 ± 0.74	9.51 ± 1.04	-	-
22	7.24 ± 0.47	9.61 ± 0.56	-	-
24	7.61 ± 0.91	9.74 ± 1.02	-	-

- no measurement because shelf – life was ended.

Table 4.28 a* value changes of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Clear plastic bag			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	3.85 ± 2.39	3.85 ± 2.39	3.85 ± 2.39	3.85 ± 2.39
2	4.14 ± 0.57	3.55 ± 1.01	3.56 ± 0.51	3.72 ± 0.67
4	4.01 ± 0.92	3.21 ± 0.54	5.43 ± 0.94	3.94 ± 0.54
6	4.83 ± 1.01	3.72 ± 1.26	5.50 ± 0.95	4.08 ± 0.42
8	5.55 ± 0.49	3.39 ± 0.77	5.45 ± 1.02	4.30 ± 0.67
10	4.91 ± 1.09	3.62 ± 0.75	5.28 ± 0.97	4.33 ± 1.18
12	5.18 ± 0.67	4.31 ± 0.63	5.37 ± 0.95	4.65 ± 0.66
14	5.63 ± 0.43	5.45 ± 1.06	5.72 ± 0.43	5.96 ± 0.52
16	6.67 ± 0.94	5.68 ± 0.48	5.80 ± 1.34	6.93 ± 1.16
18	7.12 ± 0.62	6.64 ± 0.79	-	-
20	7.14 ± 0.77	7.08 ± 1.39	-	-
22	7.98 ± 0.82	8.05 ± 1.43	-	-
24	8.05 ± 0.76	9.85 ± 0.50	-	-

- no measurement because shelf – life was ended.

Table 4.29 b* value changes of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag with nitrogen			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	14.56 ± 1.89	14.56 ± 1.89	14.56 ± 1.89	14.56 ± 1.89
2	12.39 ± 0.91	11.54 ± 1.50	7.71 ± 0.86	5.69 ± 0.49
4	11.98 ± 0.96	10.78 ± 1.55	7.53 ± 2.39	4.71 ± 1.61
6	11.76 ± 0.89	10.72 ± 1.00	6.60 ± 2.01	3.62 ± 0.69
8	11.47 ± 0.97	9.82 ± 0.61	6.11 ± 1.92	3.17 ± 0.57
10	11.46 ± 0.85	9.69 ± 0.81	4.80 ± 1.49	2.89 ± 0.67
12	11.63 ± 1.12	9.74 ± 1.63	4.02 ± 0.62	2.49 ± 0.71
14	11.53 ± 1.61	9.64 ± 0.89	2.23 ± 0.73	2.68 ± 0.26
16	11.42 ± 1.22	9.42 ± 0.92	2.44 ± 0.70	1.01 ± 0.10
18	11.27 ± 1.34	9.08 ± 1.39	-	-
20	11.16 ± 1.19	9.08 ± 0.36	-	-
22	10.50 ± 0.96	8.99 ± 0.74	-	-
24	11.04 ± 1.19	8.13 ± 1.10	-	-

\- no measurement because shelf – life was ended.

Table 4.30 b* value changes of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag without nitrogen			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	14.56 ± 1.89	14.56 ± 1.89	14.56 ± 1.89	14.56 ± 1.89
2	13.27 ± 2.29	11.73 ± 1.39	7.69 ± 0.77	5.63 ± 0.94
4	12.38 ± 0.74	11.43 ± 0.66	7.41 ± 1.17	5.25 ± 0.17
6	11.51 ± 0.83	11.41 ± 0.75	7.21 ± 0.57	5.54 ± 0.36
8	11.59 ± 0.63	11.27 ± 0.86	7.00 ± 0.86	5.57 ± 0.38
10	11.39 ± 0.86	10.95 ± 0.73	6.93 ± 2.76	4.33 ± 0.92
12	11.36 ± 0.67	10.79 ± 1.00	5.17 ± 1.77	3.22 ± 1.20
14	11.16 ± 1.28	10.63 ± 0.47	5.19 ± 0.86	1.70 ± 0.06
16	11.21 ± 1.25	10.47 ± 0.98	3.74 ± 0.84	1.45 ± 0.14
18	11.17 ± 1.17	10.42 ± 1.18	-	-
20	11.05 ± 0.72	10.28 ± 0.72	-	-
22	10.95 ± 1.36	10.06 ± 1.45	-	-
24	10.35 ± 0.97	10.05 ± 1.27	-	-

- no measurement because shelf – life was ended.

Table 4.31 b* value changes of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Clear plastic bag			
	4ºC	25ºC	35ºC	45ºC
0	14.56 ± 1.89	14.56 ± 1.89	14.56 ± 1.89	14.56 ± 1.89
2	11.70 ± 1.36	11.24 ± 1.46	6.01 ± 1.38	2.81 ± 0.86
4	10.36 ± 2.22	10.50 ± 0.47	6.00 ± 0.44	2.54 ± 0.27
6	9.63 ± 1.89	9.91 ± 1.31	6.09 ± 0.81	2.44 ± 0.89
8	9.29 ± 1.14	9.83 ± 1.42	4.15 ± 0.82	1.48 ± 0.29
10	9.36 ± 0.45	9.61 ± 0.99	3.98 ± 1.46	1.27 ± 0.24
12	9.91 ± 1.92	7.07 ± 1.10	3.93 ± 1.34	1.04 ± 0.48
14	9.81 ± 0.68	6.91 ± 0.33	3.56 ± 0.83	1.10 ± 0.67
16	9.15 ± 0.65	6.93 ± 0.24	2.61 ± 1.39	0.85 ± 0.24
18	9.26 ± 1.09	5.15 ± 0.59	-	-
20	9.23 ± 0.83	5.08 ± 0.75	-	-
22	9.21 ± 0.87	4.74 ± 0.73	-	-
24	8.27 ± 1.05	4.48 ± 0.69	-	-

\- no measurement because shelf – life was ended.

Table 4.33 – 4.35 show the changes of IML samples stored in different packaging types and temperatures during 6 months. As ANOVA results (Table 4.32), the effects of temperatures of storage within storage period on the textures of longan sample were significant ($p \leq 0.05$) while the package types were not affected on their textures. In general, the effect of interaction between temperatures of storage and packaging types within storage period did not significantly ($p > 0.05$) affect on the hardness characteristic of IML samples. It can be seen clearly that the texture of IML stored at high temperature was harder than that at low temperature (Table 4.20). In phase 4.1.1, the hardness of commercial dried longan was reported about 6.71 ± 1.79 (N). Moreover, Krit *et al.* (2015) reported that the hardness of normal dried longan dried by hot air oven was 9.76 ± 1.56 (N). It can be compared with IML in this study, although there were significant effects of temperature of storage and packing types within storage period on hardness properties of longan samples, their textures were softer than the normal dried longan.

From Table 4.33, 4.34 and 4.35, the hardness of IML products packed in Al bag with nitrogen was softer than that of IML products packed in Al bag without nitrogen and clear plastic bag. Therefore, IML products packed in Al bag with nitrogen could be kept longer than the others.

Table 4.32 ANOVA for texture analysis of intermediate moisture longan during storage.

Source of variation	**df**	**Mean square**	
		Hardness	**P - value**
Temperature of storage (TS)	3	110.97	0.000
Packaging types (PT)	2	6.841	0.000
Storage period (SP)	12	36.44	0.000
Effect of (TS x PT)	6	2.12	0.004
Error		0.65	

Table 4.33 Texture analysis of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag with nitrogen			
	Hardness (N)			
	4ºC	**25ºC**	**35ºC**	**45ºC**
0	1.56 ± 0.25	1.56 ± 0.25	1.56 ± 0.25	1.56 ± 0.25
2	1.71 ± 0.26	2.22 ± 0.63	3.22 ± 1.38	3.59 ± 0.58
4	1.71 ± 0.50	2.33 ± 0.74	3.26 ± 1.25	3.77 ± 1.36
6	1.80 ± 0.12	2.36 ± 1.08	3.27 ± 1.72	3.83 ± 0.54
8	1.96 ± 0.71	2.63 ± 0.44	3.87 ± 1.62	3.83 ± 0.48
10	1.82 ± 0.37	2.81 ± 0.63	3.96 ± 0.58	4.03 ± 0.64
12	1.83 ± 0.42	2.85 ± 0.31	4.04 ± 1.17	4.15 ± 0.43
14	1.88 ± 0.22	2.89 ± 0.45	4.01 ± 0.96	4.15 ± 0.95
16	1.91 ± 0.52	3.21 ± 0.44	4.36 ± 0.42	4.25 ± 0.75
18	1.97 ± 0.37	3.42 ± 0.23	-	-
20	2.90 ± 0.73	3.56 ± 1.08	-	-
22	2.45 ± 0.88	3.59 ± 0.54	-	-
24	3.20 ± 0.46	3.89 ± 0.96	-	-

- no measurement because shelf – life was ended.

Table 4.34 Texture analysis of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag without nitrogen			
	Hardness (N)			
	4ºC	25ºC	35ºC	45ºC
0	1.56 ± 0.25	1.56 ± 0.25	1.56 ± 0.25	1.56 ± 0.25
2	2.05 ± 0.25	2.14 ± 0.70	3.27 ± 1.06	3.64 ± 0.71
4	2.05 ± 0.36	2.19 ± 0.57	3.49 ± 0.86	3.56 ± 0.83
6	2.11 ± 0.27	2.24 ± 0.54	3.54 ± 1.91	3.90 ± 0.84
8	2.04 ± 0.50	2.35 ± 0.15	3.72 ± 1.22	4.03 ± 0.49
10	2.12 ± 0.69	2.33 ± 0.21	3.96 ± 0.89	4.06 ± 0.70
12	2.15 ± 0.65	2.51 ± 0.43	3.88 ± 0.51	4.05 ± 0.55
14	2.28 ± 0.46	2.56 ± 0.67	3.93 ± 0.81	4.37 ± 0.60
16	2.35 ± 0.37	2.81 ± 0.84	4.23 ± 0.47	4.33 ± 0.60
18	2.53 ± 0.32	3.10 ± 0.92	-	-
20	3.33 ± 1.02	3.11 ± 0.92	-	-
22	3.38 ± 1.20	3.46 ± 0.98	-	-
24	4.19 ± 0.82	4.03 ± 0.72	-	-

- no measurement because shelf – life was ended.

Table 4.35 Texture analysis of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45^{o}C).

Storage period (weeks)	Clear plastic bag			
	Hardness (N)			
	4^{o}C	**25^{o}C**	**35^{o}C**	**45^{o}C**
0	1.56 ± 0.25	1.56 ± 0.25	1.56 ± 0.25	1.56 ± 0.25
2	2.14 ± 0.58	2.04 ± 0.65	3.69 ± 1.05	3.78 ± 0.84
4	2.15 ± 0.54	2.12 ± 0.86	3.99 ± 1.18	3.79 ± 0.82
6	2.24 ± 0.73	2.51 ± 1.09	3.93 ± 1.19	3.84 ± 0.53
8	2.39 ± 0.89	2.96 ± 1.29	3.99 ± 0.81	3.99 ± 0.75
10	2.49 ± 1.02	2.99 ± 0.60	4.04 ± 1.03	4.05 ± 1.39
12	2.43 ± 0.73	3.12 ± 0.55	4.00 ± 0.43	4.28 ± 0.62
14	2.77 ± 0.47	3.08 ± 0.53	4.61 ± 0.90	4.65 ± 0.74
16	2.87 ± 0.57	3.06 ± 0.61	4.65 ± 0.72	5.75 ± 0.69
18	3.16 ± 0.61	3.10 ± 0.54	-	-
20	3.31 ± 0.83	3.10 ± 0.84	-	-
22	3.37 ± 0.73	3.31 ± 0.73	-	-
24	4.24 ± 0.82	4.20 ± 1.86	-	-

- no measurement because shelf – life was ended.

The changes of antioxidant capacities of intermediate moisture longan were presented in Table 4.37 – 4.39. From results of ANOVA, the temperatures of storage and package types within storage period was significantly affected ($p \leq 0.05$) on antioxidant capacity of IML product (Table 4.36). The phenolic content of longan fruit was found to be 80.32 ± 5.38 mg GAE/ 100g (Fu *et al.* 2011) related with DPPH radical scavenging activity of longan aril was 75.76 ± 2.99 %. It was then reduced to 43.29 ± 3.17 % after immersing osmotic solution and drying at 60^{o}C for 8 hours. However, in some packages this trend is not exactly due to their antioxidant capacities depended on food structure and food components. The activities of antioxidants depend not only on food structures, food compositions but also on many other factors such as concentration, temperature, light, and type of substrate and availability of oxygen (Porkony *et al.*, 2001). The DPPH radical scavenging activity is widely used to evaluate antioxidant ability in a relatively short time.

This method is based on the reduction of ethanolic DPPH solution (purple color) in the presence of a hydrogen donating antioxidant, the non-radical form DPPH–H (yellow color) is formed (Yang *et al.*, 2010). Moreover, it can be known clearly that plant phenolic content are highly effective free radical scavengers and antioxidants and antioxidant activity of fruits. Therefore, it should be a close relationship between the content of phenolic compounds and antioxidant activity (Pan *et al.*, 2008).

Table 4.37, 4.38 and 4.39, the antioxidant capacities of IML products packed in Al bag with nitrogen reduced slightly compared with IML products packed in Al bag without nitrogen and clear plastic bag. Therefore, IML products packed in Al bag with nitrogen could be kept longer than the others.

Table 4.36 ANOVA for antioxidant capacities of intermediate moisture longan during storage period.

Source of variation	**df**	**Mean square**	
		Antioxidant capacity	**P - value**
Temperature of storage (TS)	3	218.44	0.000
Packaging types (PT)	2	280.24	0.000
Storage period (SP)	7	1175.39	0.000
Effect of (TS x PT)	6	58.07	0.003
Error		16.89	

Table 4.37 Antioxidant capacities of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag with nitrogen			
	% DPPH inhibition			
	4ºC	25ºC	35ºC	45ºC
0	43.29 ± 3.17	43.29 ± 3.17	43.29 ± 3.17	43.29 ± 3.17
4	44.11 ± 3.27	42.67 ± 2.03	43.36 ± 1.94	35.42 ± 1.65
8	46.33 ± 2.22	38.20 ± 1.67	37.56 ± 1.04	45.80 ± 1.64
12	34.91 ± 1.92	30.06 ± 0.72	38.43 ± 2.19	30.74 ± 0.76
16	32.43 ± 2.39	31.52 ± 1.35	31.56 ± 2.03	42.20 ± 1.75
20	37.86 ± 0.84	30.45 ± 1.74	-	-
24	42.40 ± 3.63	30.15 ± 0.91	-	-

- no measurement because shelf – life was ended.

Table 4.38 Antioxidant capacities of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC).

Storage period (weeks)	Al bag without nitrogen			
	% DPPH inhibition			
	4ºC	25ºC	35ºC	45ºC
0	43.29 ± 3.17	43.29 ± 3.17	43.29 ± 3.17	43.29 ± 3.17
4	42.97 ± 4.61	36.70 ± 1.61	41.52 ± 4.82	36.76 ± 1.78
8	36.58 ± 0.88	34.60 ± 1.92	39.57 ± 0.68	39.93 ± 1.92
12	35.79 ± 0.67	30.04 ± 0.81	28.32 ± 1.64	29.56 ± 1.03
16	32.93 ± 0.68	30.68 ± 0.68	30.33 ± 1.11	39.55 ± 2.47
20	34.05 ± 0.38	28.77 ± 4.44	-	-
24	31.05 ± 2.52	25.72 ± 5.33	-	-

- no measurement because shelf – life was ended.

Table 4.39 Antioxidant capacities of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45°C).

Storage period (weeks)	Clear plastic bag			
	% DPPH inhibition			
	4°C	**25°C**	**35°C**	**45°C**
0	43.29 ± 3.17	43.29 ± 3.17	43.29 ± 3.17	43.29 ± 3.17
4	39.47 ± 1.36	31.89 ± 3.58	34.06 ± 1.88	36.82 ± 0.77
8	34.06 ± 0.84	49.97 ± 1.83	39.24 ± 1.17	37.78 ± 2.33
12	30.93 ± 1.13	29.22 ± 0.57	31.73 ± 1.54	35.23 ± 0.53
16	30.11 ± 2.40	28.34 ± 4.45	32.13 ± 1.45	42.45 ± 0.57
20	29.59 ± 1.09	27.48 ± 0.96	-	-
24	28.27 ± 5.64	20.33 ± 1.63	-	-

\- no measurement because shelf – life was ended.

Table 4.40 shows the effect of temperatures of storage, packaging types within storage period on sensory evaluation scores. Panelists gave overall acceptance scores ranging between 3.3 (closed to dislike moderately) and 6.6 (closed to like moderately) (Table 4.41 – 4.43). The effects of interaction between temperatures and packaging types on overall acceptability, odor and color of longan sample were significant ($p \leq 0.05$). In shelf life testing scores, the panelists' acceptance could be found at testing score of above 5.0 (Chaikham *et al.*, 2013). Therefore, the shelf life would be ended corresponding with the sensorial scores below 5.0. The sensorial scores of IML at beginning period was 6.2 ± 1.4 for overall liking, 6.3 ± 1.5 for color testing and 6.0 ± 1.7 for taste testing. From the results in Table 4.43, IML packed in Al bag with and without nitrogen and clear plastic bags at 4°C and 25°C were acceptable up to 4 months of storage period.

Table 4.37, 4.38 and 4.39, the acceptance scores of IML products packed in Al bag with nitrogen were higher than those of IML products packed in Al bag without nitrogen and clear plastic bag during storage period. Therefore, the qualities of IML products packed in Al bag with nitrogen might be kept maintained longer than the others.

Table 4.40 ANOVA for sensory evaluation scores of intermediate moisture longan during storage period.

Source of variation	df	Mean square					
		Overall acceptance	P – value	Color	P - value	Odor	P - value
Temperature of storage (TS)	3	811.93	0.000	1186.74	0.000	511.53	0.000
Packaging types (PT)	2	124.35	0.000	210.35	0.000	51.13	0.000
Storage period (SP)	8	97.82	0.000	78.50	0.000	78.39	0.000
Effect of (TS x PT)	6	6.62	0.012	22.33	0.000	6.34	0.023
Error		2.44		2.43		2.59	

Table 4.41 Acceptance scores of intermediate moisture longan packed in Al bag with nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC) (n = 50).

	Storage period (weeks)	**Al bag with Nitrogen**			
		4ºC	**25ºC**	**35ºC**	**45ºC**
Overall acceptance	3	6.4 ± 1.3	6.2 ± 1.5	5.9 ± 1.5	5.7 ± 1.5
	6	6.5 ± 1.5	6.3 ± 1.6	5.7 ± 1.6	5.0 ± 1.6
	9	6.2 ± 1.6	5.8 ± 1.3	5.4 ± 1.5	4.3 ± 1.9
	12	6.3 ± 1.5	5.8 ± 1.4	5.1 ± 1.6	4.0 ± 1.7
	15	6.3 ± 1.5	5.3 ± 1.4	4.1 ± 1.8	-
	18	6.3 ± 1.5	4.9 ± 1.3	-	-
	21	6.1 ± 1.3	-	-	-
	24	5.6 ± 1.3	-	-	-
Color	3	6.6 ± 1.3	6.2 ± 1.4	6.1 ± 1.6	5.6 ± 1.7
	6	6.5 ± 1.3	6.2 ± 1.2	5.9 ± 1.6	4.9 ± 1.7
	9	6.5 ± 1.6	6.1 ± 1.4	5.4 ± 1.5	4.1 ± 1.7
	12	6.2 ± 1.1	6.1 ± 1.5	5.1 ± 1.8	-
	15	6.3 ± 1.0	5.6 ± 1.4	4.1 ± 1.9	-
	18	6.1 ± 1.1	4.7 ± 1.2	-	-
	21	6.0 ± 1.0	-	-	-
	24	5.8 ± 1.1	-	-	-
Odor	3	6.0 ± 1.6	6.0 ± 1.7	5.8 ± 1.5	5.5 ± 1.7
	6	6.1 ± 1.6	5.8 ± 1.7	5.6 ± 1.6	5.1 ± 1.6
	9	6.0 ± 1.8	5.4 ± 1.4	5.1 ± 1.4	4.4 ± 1.8
	12	6.0 ± 1.5	5.5 ± 1.6	4.8 ± 1.6	4.1 ± 1.7
	15	6.0 ± 1.6	5.2 ± 1.5	3.9 ± 1.7	-
	18	5.9 ± 1.7	4.9 ± 1.5	-	-
	21	5.8 ± 1.5	-	-	-
	24	5.4 ± 1.3	-	-	-

\- no measurement because shelf – life was ended.

Table 4.42 Acceptance scores of intermediate moisture longan packed in Al bag without nitrogen during storage time at different temperatures (4, 25, 35 and 45ºC) (n = 50).

	Storage period (weeks)	**Al bag without nitrogen**			
		4ºC	**25ºC**	**35ºC**	**45ºC**
Overall acceptance	3	6.3 ± 1.4	5.9 ± 1.4	4.8 ± 1.4	4.1 ± 1.5
	6	6.5 ± 1.3	5.7 ± 1.3	4.5 ± 1.7	3.9 ± 1.9
	9	6.2 ± 1.5	5.4 ± 1.2	-	-
	12	6.1 ± 1.5	5.6 ± 1.3	-	-
	15	6.2 ± 1.4	5.1 ± 1.5	-	-
	18	5.4 ± 1.2	4.7 ± 1.1	-	-
	21	5.3 ± 1.1	-	-	-
	24	4.9 ± 1.1	-	-	-
Color	3	6.4 ± 1.3	6.0 ± 1.3	4.8 ± 1.6	3.5 ± 1.8
	6	6.5 ± 1.4	5.8 ± 1.4	4.4 ± 1.9	3.3 ± 1.9
	9	6.1 ± 1.5	5.5 ± 1.2	-	-
	12	6.5 ± 1.6	5.6 ± 1.4.	-	-
	15	6.3 ± 1.4	5.2 ± 1.6	-	-
	18	5.8 ± 1.2	4.8 ± 1.3	-	-
	21	5.7 ± 1.2	-	-	-
	24	5.0 ± 1.2	-	-	-
Odor	3	6.1 ± 1.5	6.1 ± 1.5	4.8 ± 1.6	4.5 ± 1.8
	6	6.0 ± 1.5	5.8 ± 1.7	4.7 ± 1.7	4.2 ± 1.7
	9	5.7 ± 1.4	5.2 ± 1.3	-	-
	12	5.8 ± 1.5	5.5 ± 1.5	-	-
	15	6.1 ± 1.6	5.0 ± 1.6	-	-
	18	5.6 ± 1.4	4.7 ± 1.3	-	-
	21	5.4 ± 1.2	-	-	-
	24	-	-	-	-

- no measurement because shelf – life was ended.

Table 4.43 Acceptance scores of intermediate moisture longan packed in clear plastic bag during storage time at different temperatures (4, 25, 35 and 45ºC) (n = 50).

	Storage period (weeks)	**Clear plastic bag**			
		4ºC	**25ºC**	**35ºC**	**45ºC**
Overall acceptance	3	6.4 ± 1.3	5.7 ± 1.6	5.2 ± 1.4	4.5 ± 1.6
	6	6.4 ± 1.3	5.7 ± 1.3	4.8 ± 1.6	4.1 ± 1.9
	9	6.2 ± 1.4	5.4 ± 1.3	4.3 ± 1.7	-
	12	6.2 ± 1.6	4.9 ± 1.3	-	-
	15	6.4 ± 1.5	4.8 ± 1.5	-	-
	18	5.7 ± 1.4	-	-	-
	21	5.5 ± 1.2	-	-	-
	24	4.6 ± 1.3	-	-	-
Color	3	6.6 ± 1.6	5.9 ± 1.6	4.5 ± 1.5	3.6 ± 1.8
	6	6.6 ± 1.5	5.2 ± 1.5	4.6 ± 1.5	3.3 ± 1.6
	9	6.2 ± 1.6	5.5 ± 1.4	4.3 ± 1.7	-
	12	6.5 ± 1.5	4.9 ± 1.2	-	-
	15	6.6 ± 1.5	4.8 ± 1.5	-	-
	18	5.9 ± 1.3	-	-	-
	21	5.6 ± 1.1	-	-	-
	24	4.7 ± 1.3	-	-	-
Odor	3	6.0 ± 1.5	5.6 ± 1.5	5.2 ± 1.7	4.6 ± 1.5
	6	6.0 ± 1.4	5.5 ± 1.5	5.0 ± 1.7	4.5 ± 1.8
	9	5.9 ± 1.3	5.4 ± 1.4	4.7 ± 1.7	-
	12	5.9 ± 1.5	5.1 ± 1.2	4.5 ± 1.6	-
	15	6.1 ± 1.5	4.7 ± 1.4	-	-
	18	5.7 ± 1.3	4.6 ± 1.3	-	-
	21	5.5 ± 1.2	-	-	-
	24	4.8 ± 1.4	-	-	-

\- no measurement because shelf – life was ended.

4.4.2 Shelf life prediction of intermediate moisture longan

The changes of IML's qualities during 6 months of storage were indicated by different conditions of storage, especially in color and texture of IML products. There were significant differences at storage conditions between stored temperatures and packaging types ($p \leq 0.05$).

4.4.2.1 The changes of L* value of IML products during 6 months at different storage conditions

The changes of L* value of IML products were measured during 6 months at different conditions of storage. L* values was likely decline during 6 months of storage period. A quality attribute L* value which decreased during the storage time as shown in Fig. 4.6, 4.7 and 4.8 for IMLs packed into Al bag with Nitrogen, Al bag without Nitrogen and clear plastic bag for zero order reactions, respectively. The linear plot illustrates that the rate of loss of color was constant throughout the storage period.

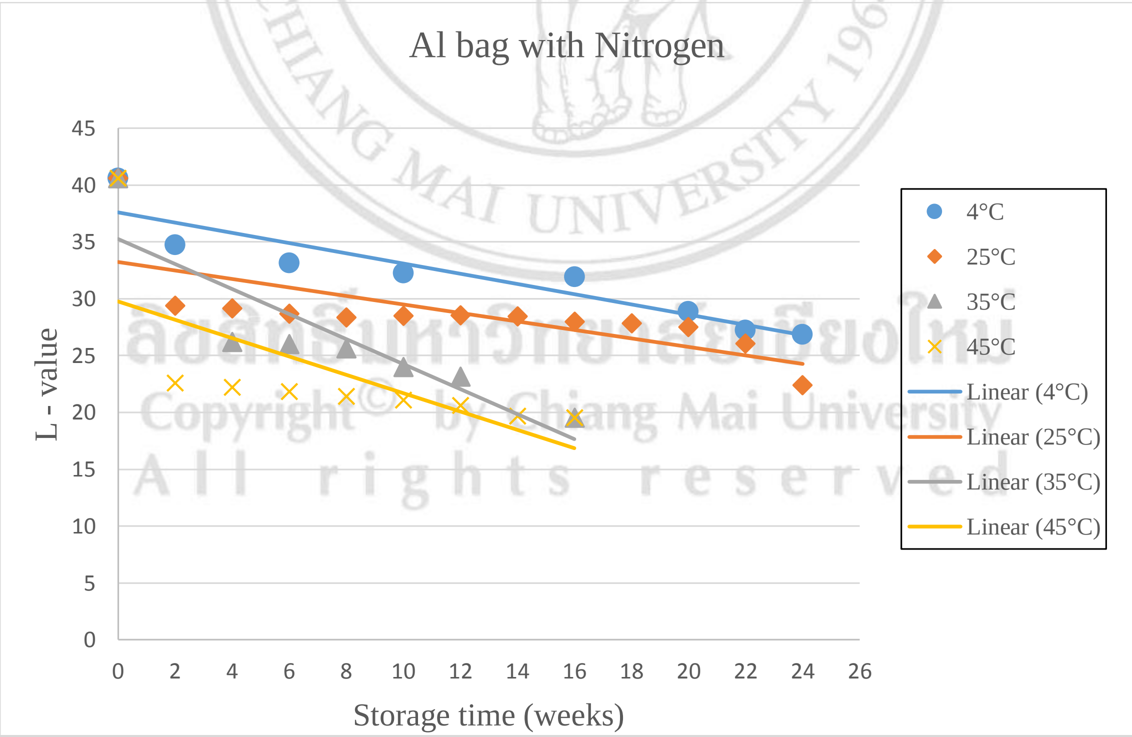

Figure 4.6 The L* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months (zero order reaction).

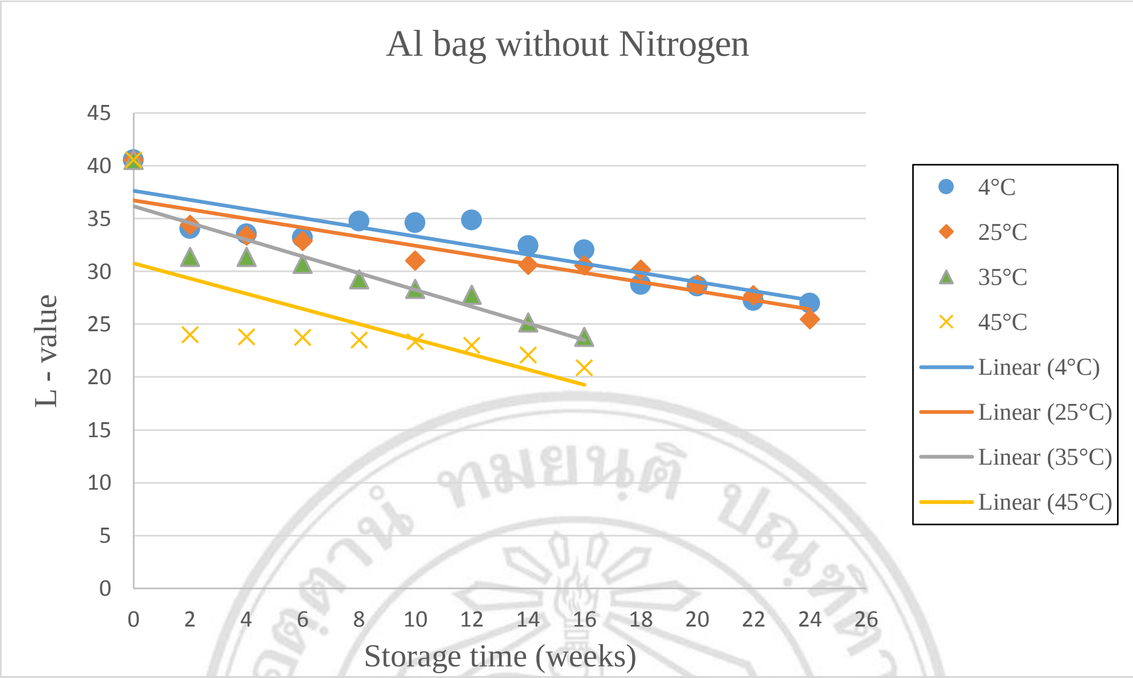

Figure 4.7 The L* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months (zero order reaction).

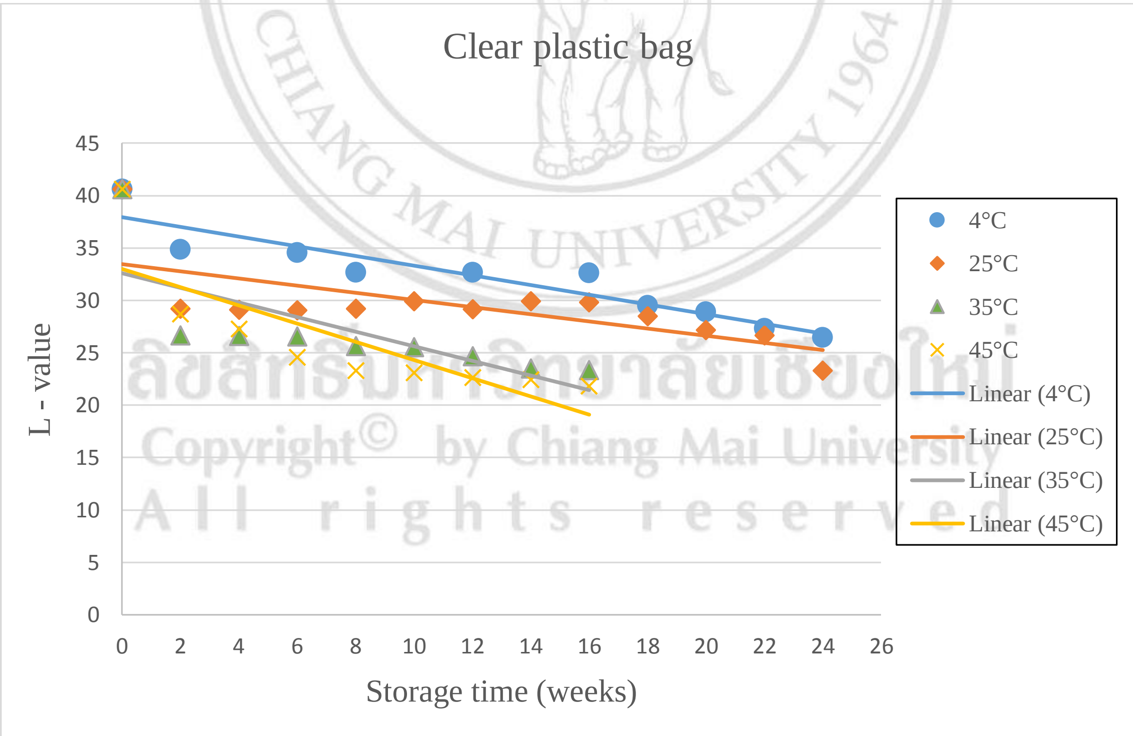

Figure 4.8 The L* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months (zero order reaction).

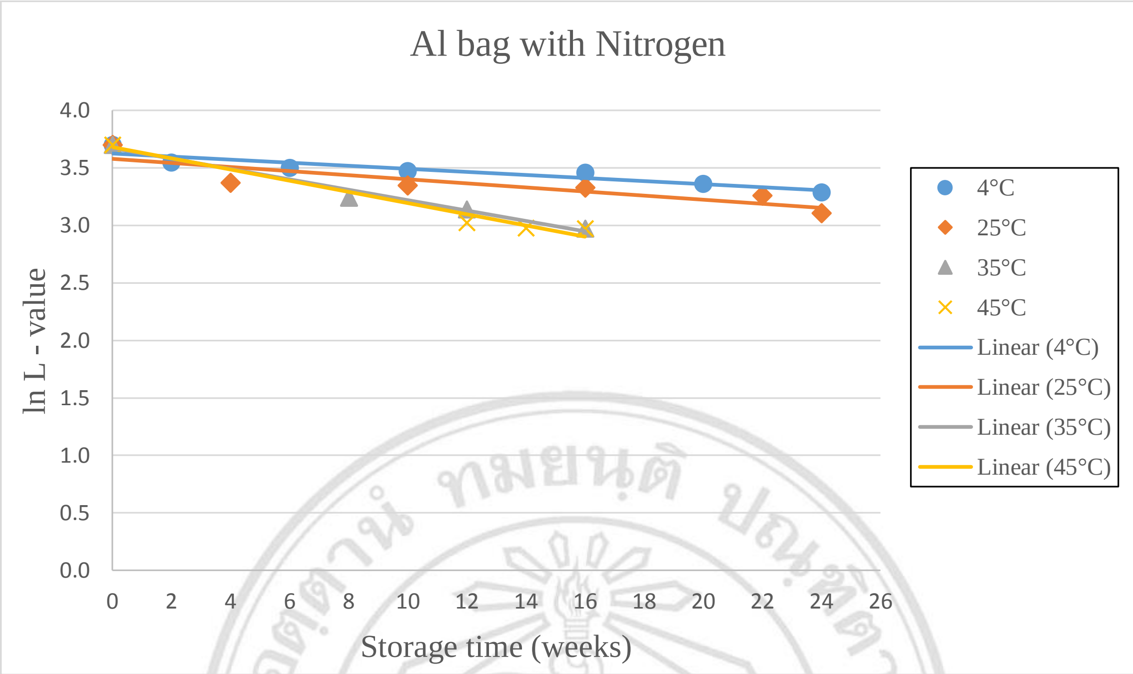

Figure 4.9 The L* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

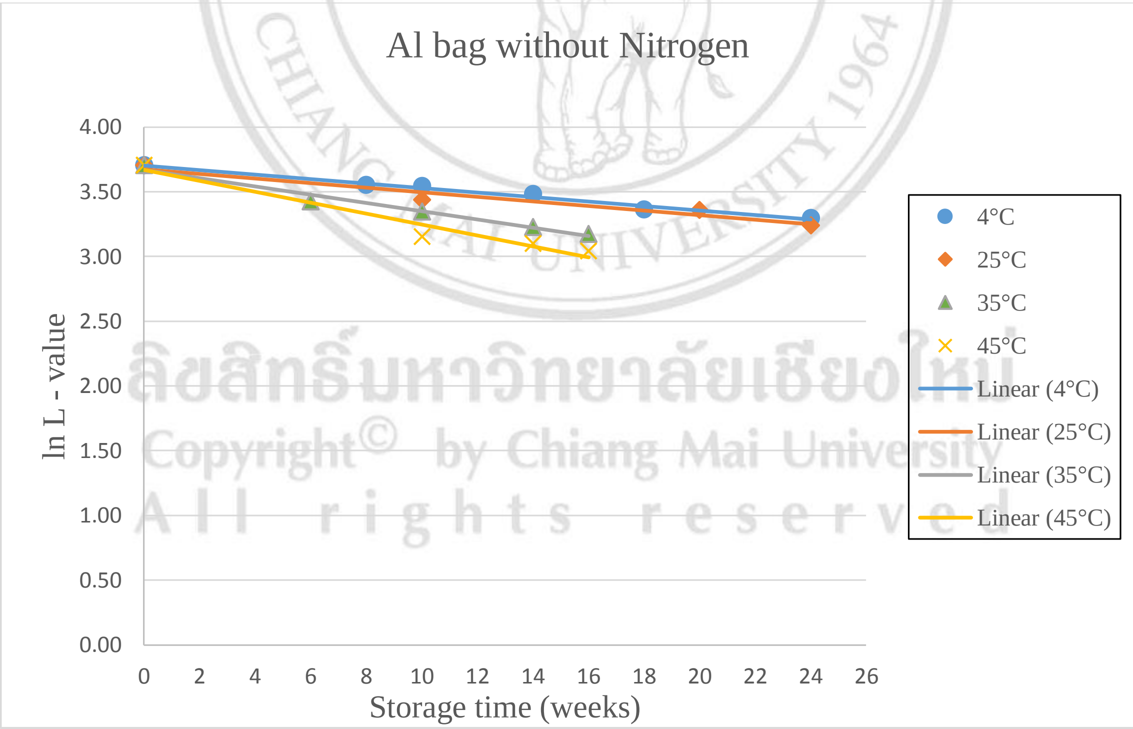

Figure 4.10 The L* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

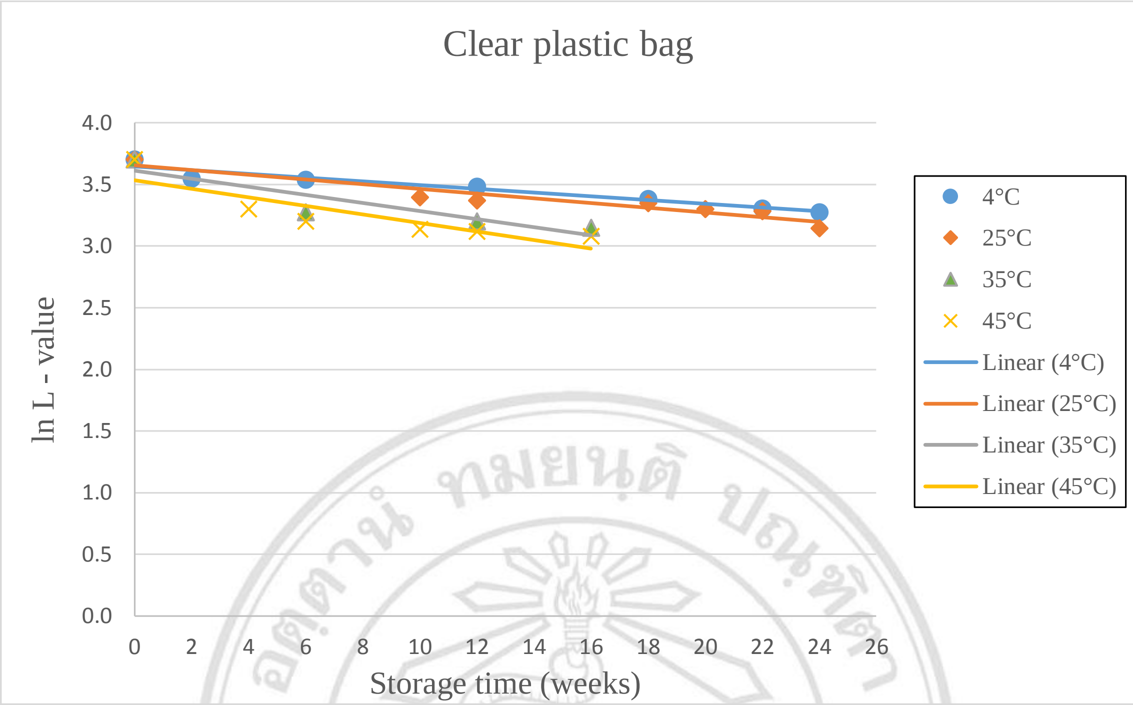

Figure 4.11 The L* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

This exponential plot between L* value attribute and storage time represented a first order reaction with n = 1, were shown in Fig. 4.9, 4.10 and 4.11 for IMLs packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag for zero order reactions, respectively. Table 4.44, 4.45 and 4.46 show the linear equations and constant rates of L* value changes of IMLs during 6 months in which IMLs were packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag and stored at 4, 25, 35 and 45°C, respectively. Arrhenius relationship was used to predict the influence of temperature on the reaction rate at each storage condition.

Table 4.44, 4.45 and 4.46 were found to be the linear with R^2 values in the range 0.768 – 0.980, 0.946 – 0.982 and 0.755 – 0.939 for Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. The first order reactions could be used to describe the changes of L* values. Therefore, Fig. 4.12, 4.13, 4.14 illustrate the temperature dependence of the reaction rate between ln k and $(1/T)$ within different storage conditions such as Al bag with nitrogen, Al bag without nitrogen and clear plastic bag at four different temperatures, respectively.

Table 4.44 Linear equation and constant rate of L* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45^{o}C during 6 months.

Reaction	Temperatures (^{o}C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.449x + 37.572	4.5×10^{-1}	0.864
	25	y= -0.373x + 33.22	3.7×10^{-1}	0.529
	35	y= -1.098x + 35.248	0.1×10^{1}	0.764
	45	y= -0.807x + 29.75	8.1×10^{-1}	0.452
First order	4	y= -0.013x + 3.628	1.3×10^{-2}	0.868
	25	y= -0.017x + 3.580	1.7×10^{-2}	0.768
	35	y= -0.045x + 3.674	4.5×10^{-2}	0.980
	45	y= -0.049x + 3.684	4.9×10^{-2}	0.972

Table 4.45 Linear equation and constant rate of L* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45^{o}C during 6 months.

Reaction	Temperatures (^{o}C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.430x + 37.621	4.3×10^{-1}	0.782
	25	y= -0.429x + 36.746	4.3×10^{-1}	0.831
	35	y= -0.792x + 36.190	7.9×10^{-1}	0.813
	45	y= -0.721x + 30.789	7.2×10^{-1}	0.444
First order	4	y= -0.017x + 3.703	1.7×10^{-2}	0.982
	25	y= -0.018x + 3.675	1.8×10^{-2}	0.946
	35	y= -0.032x + 3.671	3.2×10^{-2}	0.976
	45	y= -0.042x + 3.670	4.2×10^{-2}	0.955

Table 4.46 Linear equation and constant rate of L* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.462x + 37.572	4.6×10^{-1}	0.878
	25	y= -0.342x + 33.223	3.4×10^{-1}	0.482
	35	y= -0.694x + 35.248	6.9×10^{-1}	0.525
	45	y= -0.871x + 29.752	8.7×10^{-1}	0.648
First order	4	y= -0.015x + 3.645	1.5×10^{-2}	0.939
	25	y= -0.019x + 3.657	1.9×10^{-2}	0.904
	35	y= -0.033x + 3.614	3.3×10^{-2}	0.835
	45	y= -0.035x + 3.536	3.5×10^{-2}	0.755

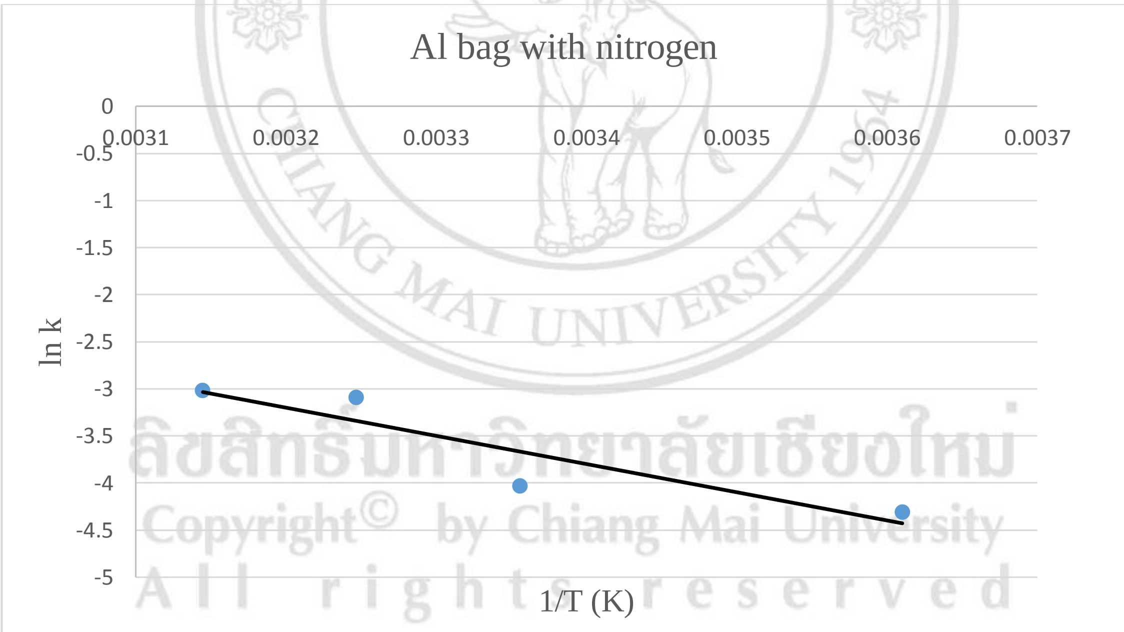

Figure 4.12 The relationship between the temperature and rate constant of L* value changes of IML products packed into Al bag with Nitrogen and stored at 4, 25, 35 and 45°C during 6 months according to Arrhenius equation.

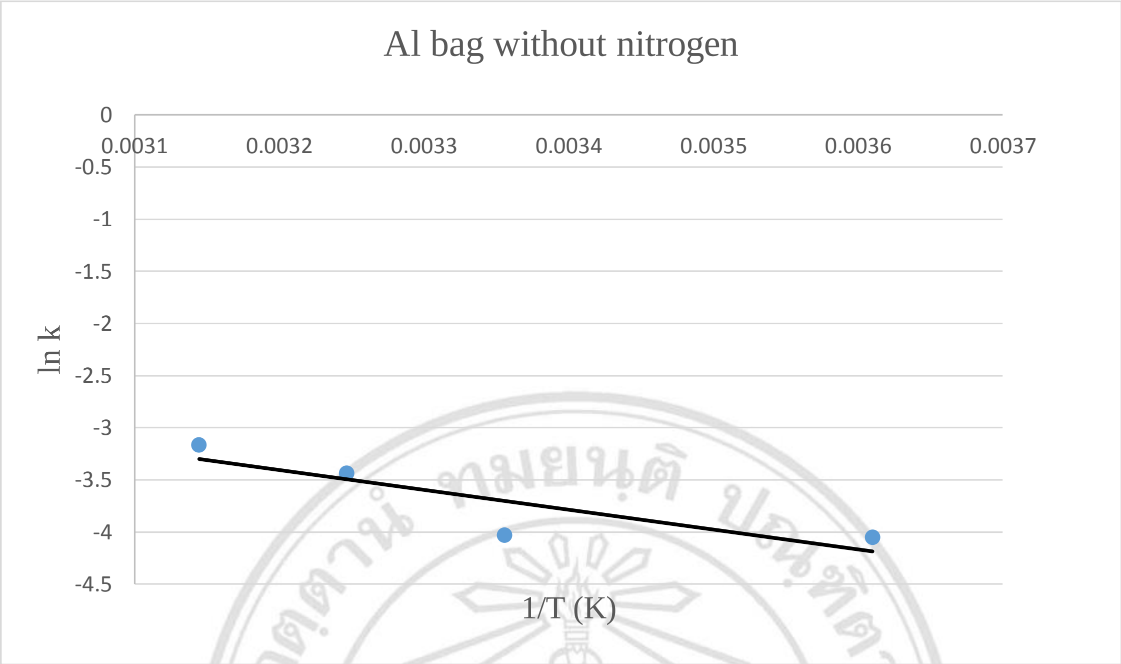

Figure 4.13 The relationship between the temperature and rate constant of L* value changes of IML products packed into Al bag without Nitrogen and stored at 4, 25, 35 and 45°C during 6 months according to Arrhenius equation.

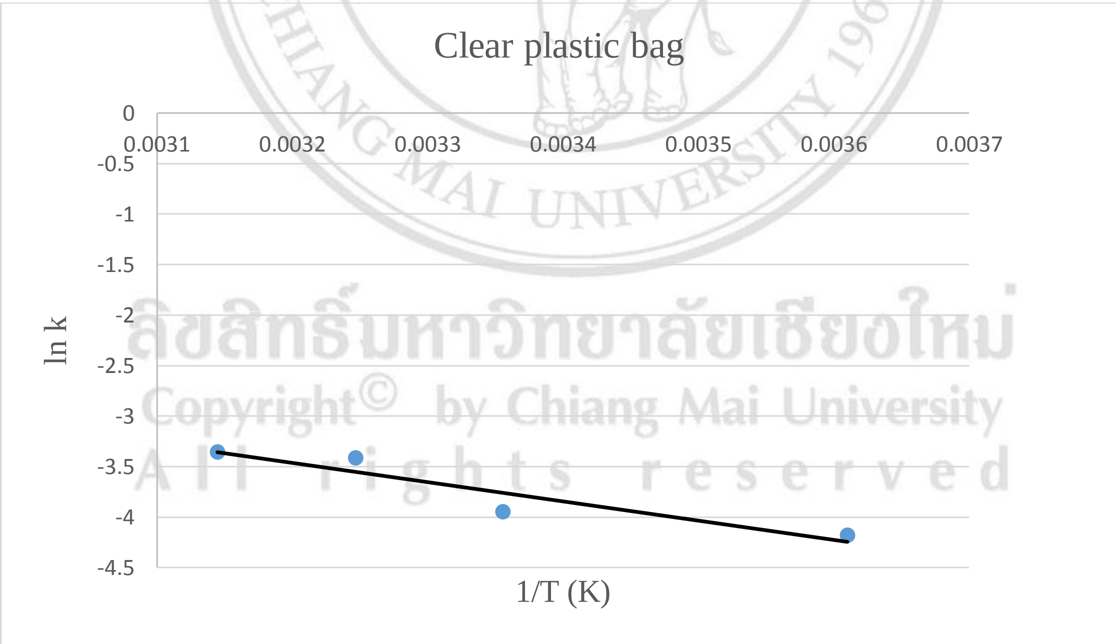

Figure 4.14 The relationship between the temperature and rate constant of L* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months according to Arrhenius equation.

Fig. 4.12, 4.13 and 4.14 show the rate constant of L* value changes and the regression equations were created from these figures. To estimate the effect of temperature on the reaction rate of color changes in L* values, values of k were estimated at different temperatures and ln k was plotted against the term of $1/T$ in a semilog graph. A straight line was obtained with a slope of - E_a/R from which the activation energy is calculated (Table 4.47).

Table 4.47 Linear equation of the rate of color deterioration (L* value change) and activation energies (E_a) of IML products stored at 4, 25, 35 and 45°C during 6 months according Arrhenius equation.

Treatments	Linear equations	R^2	E_a
Al bag with Nitrogen	$\ln k = -2996.5\ (\frac{1}{T}) + 6.3908$	0.838	24.91 kJ/mol
Al bag without Nitrogen	$\ln k = -1907.8\ (\frac{1}{T}) + 2.7004$	0.745	15.86 kJ/mol
Clear plastic bag	$\ln k = -1899.3\ (\frac{1}{T}) + 2.6129$	0.880	15.79 kJ/mol

Activation energy (E_a) could be an indirect quantitative means available to compare the samples effectively. 24.91 kJ/ mol, 15.86 kJ/ mol and 15.79 kJ/ mol are the excess energy barrier in which L* value changes need to overcome to proceed to degradation of IML products packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. In a previous study, dried longan using with osmotic solution was shown with activation energy about 35.31 kJ/ mol to reduce the L* value of dried longan packed into aluminum foil laminated plastic bags with Nitrogen (Homhuan, 2013). From Table 4.47, IML product packed in Al bag with nitrogen could be stored longer than the others.

4.4.2.2 The changes of b* value of IML products during 6 months at different storage conditions

The changes of b* value of IML products were measured during 6 months at different conditions of storage. b* values was likely increased during 6 months of storage period. A quality attribute a* value which increases during the storage time as shown in Fig. 4.15, 4.16 and 4.17 for IMLs packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag for zero order reactions, respectively. The linear plot illustrates that the rate of loss of color was constant throughout the storage period.

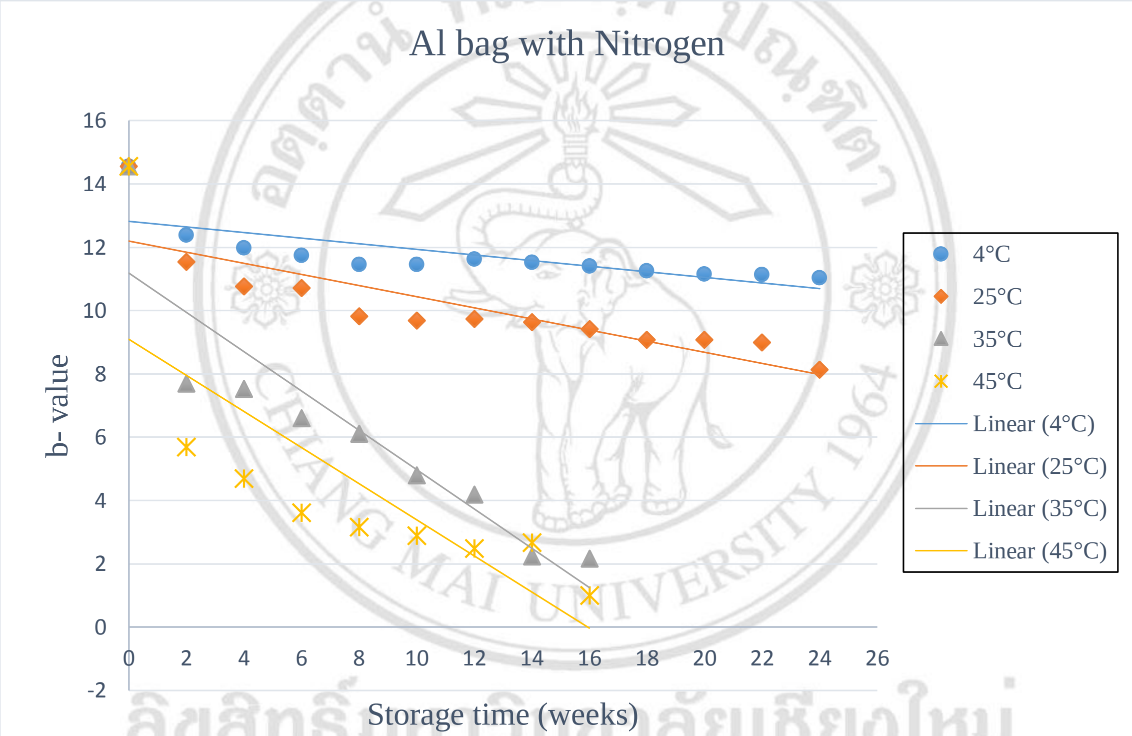

Figure 4.15 The b* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months (zero order reaction).

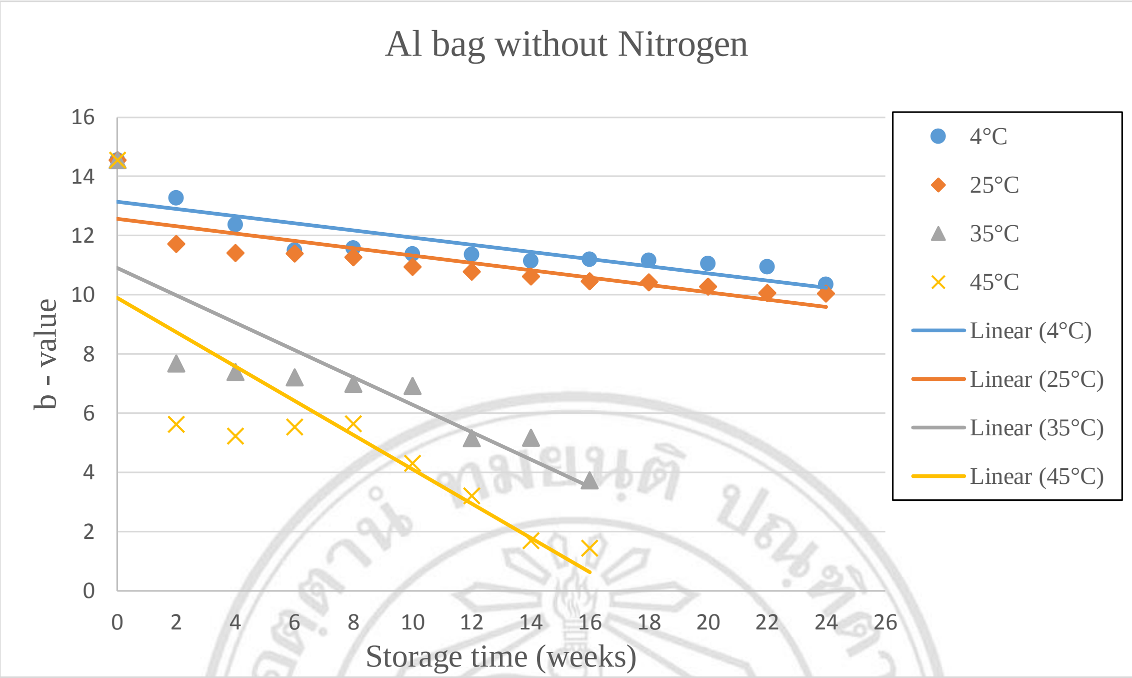

Figure 4.16 The b* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45ºC during 6 months (zero order reaction).

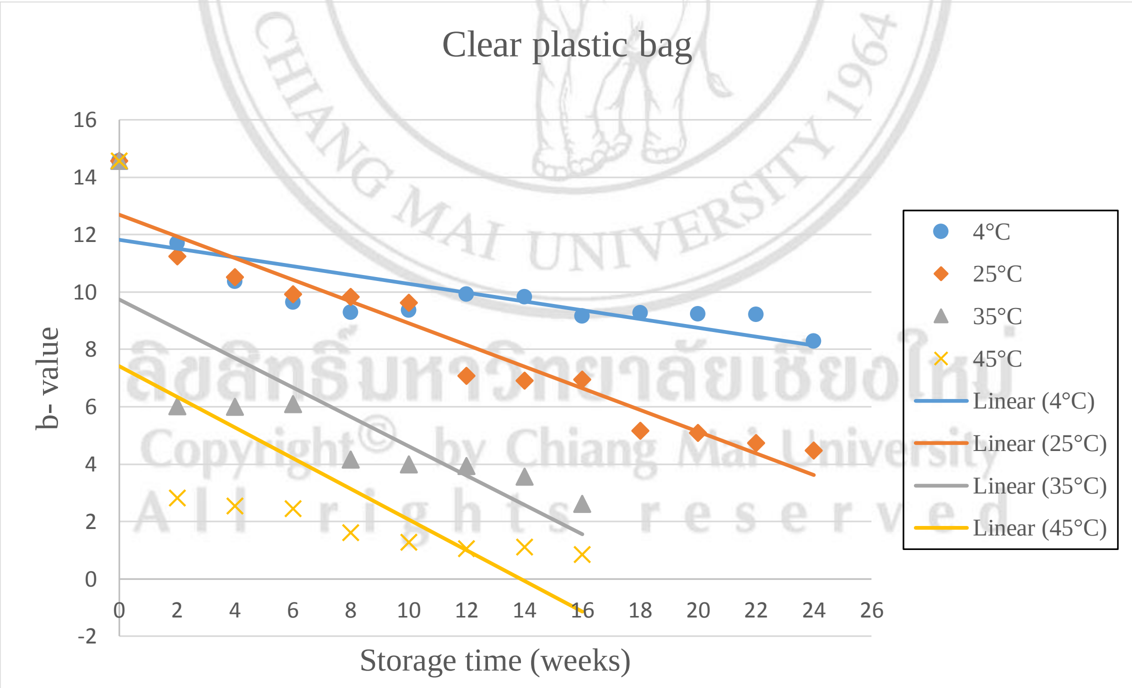

Figure 4.17 The b* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45ºC during 6 months (zero order reaction).

This exponential plot between b* value attribute and storage time represented a first order reaction with n = 1, were shown in Fig. 4.18, 4.19 and 4.20 for IMLs packed into Al bag with nitrogen, Al bag without Nitrogen and clear plastic bag for zero order reactions, respectively. Table 4.48, 4.49 and 4.50 show the linear equations and constant rates of a* value changes of IMLs during 6 months in which IMLs were packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag and stored at 4, 25, 35 and 45^{o}C, respectively. Arrhenius relationship was used to predict the influence of temperature on the reaction rate at each storage condition.

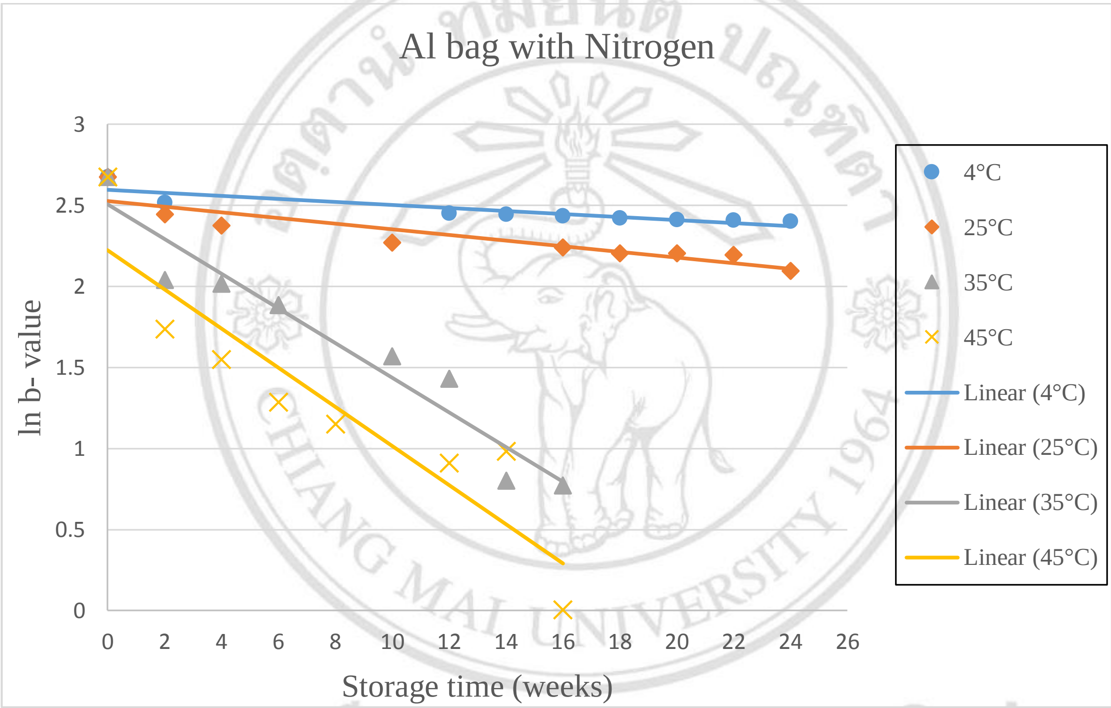

Figure 4.18 The b* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45^{o}C during 6 months (first order reaction).

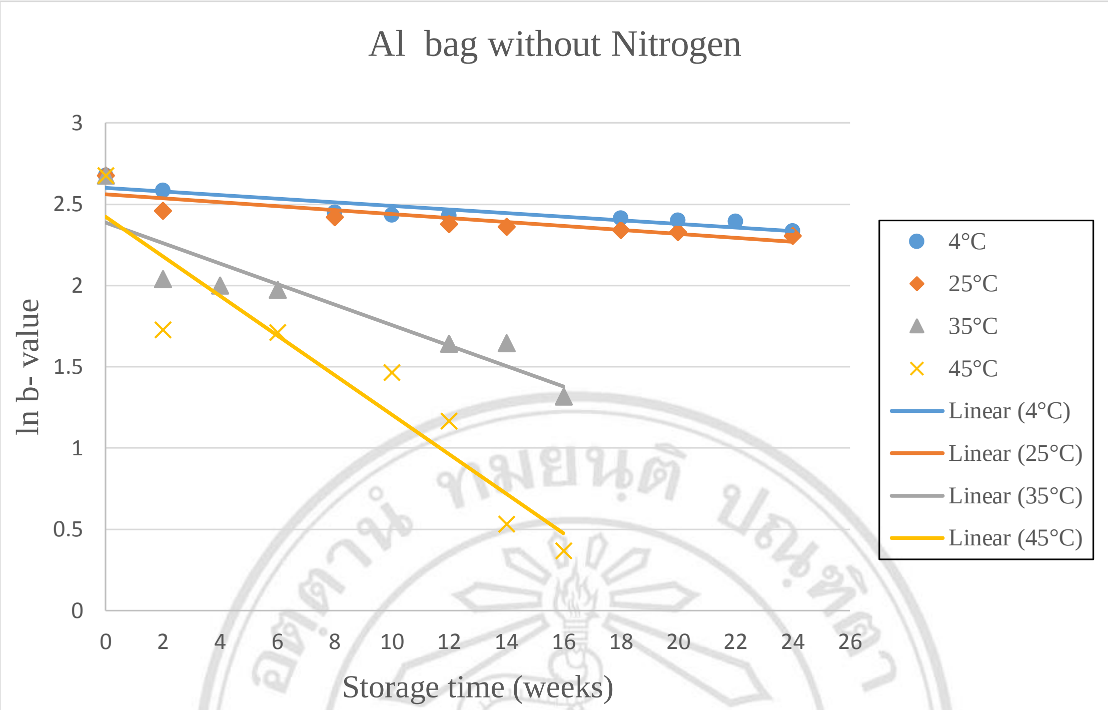

Figure 4.19 The b* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45^{o}C during 6 months (first order reaction).

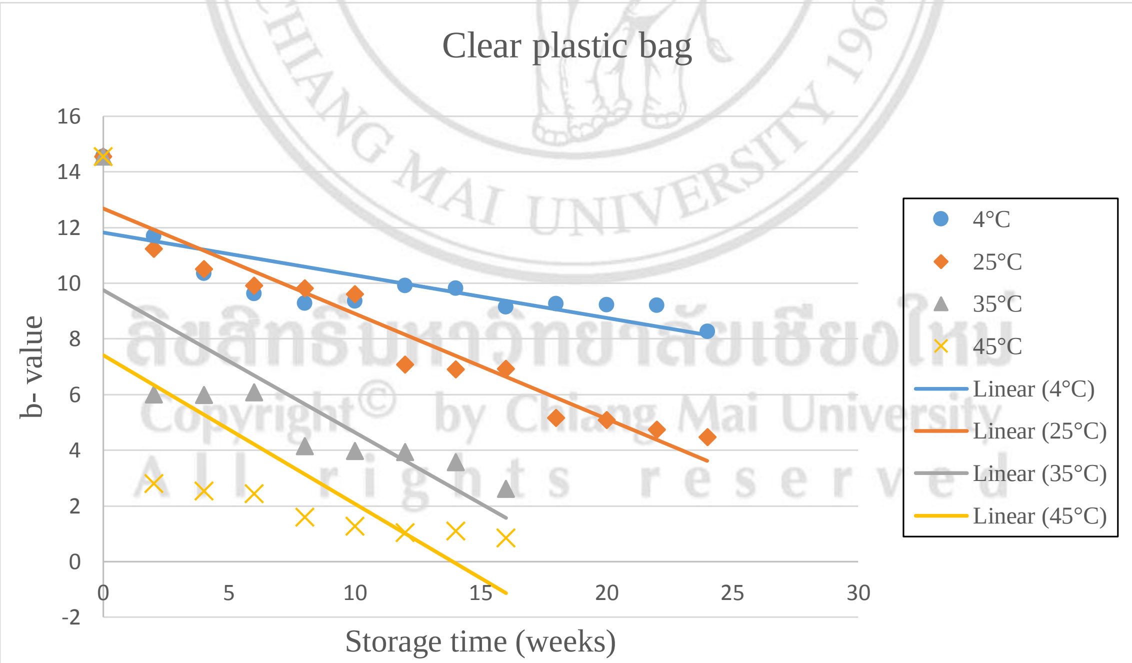

Figure 4.20 The b* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45^{o}C during 6 months (first order reaction).

Table 4.48 Linear equation and constant rate of b* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45^oC during 6 months.

Reaction	Temperatures (^oC)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.088x + 12.815	8.8×10^{-2}	0.560
	25	y= -0.175x + 12.196	1.7×10^{-1}	0.722
	35	y= -0.621x + 11.175	6.2×10^{-1}	0.825
	45	y= -0.570x + 9.096	5.7×10^{-1}	0.613
First order	4	y= -0.009x + 2.595	0.9×10^{-2}	0.785
	25	y= -0.018x + 2.527	1.8×10^{-2}	0.828
	35	y= -0.107x + 2.506	1.1×10^{-1}	0.932
	45	y= -0.121x + 2.225	1.2×10^{-1}	0.836

Table 4.49 Linear equation and constant rate of b* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45^oC during 6 months.

Reaction	Temperatures (^oC)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.121x + 13.144	1.2×10^{-1}	0.715
	25	y= -0.123x + 12.561	1.2×10^{-1}	0.665
	35	y= -0.463x + 10.913	4.6×10^{-1}	0.688
	45	y= -0.579x + 9.892	5.8×10^{-1}	0.676
First order	4	y= -0.011x + 2.601	1.1×10^{-2}	0.816
	25	y= -0.012x + 2.559	1.2×10^{-2}	0.751
	35	y= -0.063x + 2.387	6.3×10^{-2}	0.841
	45	y= -0.122x + 2.422	1.2×10^{-1}	0.885

Table 4.50 Linear equation and constant rate of b* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.153x + 11.817	1.5×10^{-1}	0.560
	25	y= -0.378x + 12.686	3.8×10^{-1}	0.927
	35	y= -0.511x + 9.745	5.1×10^{-1}	0.619
	45	y= -0.535x + 7.410	5.4×10^{-1}	0.454
First order	4	y= -0.019x + 2.507	1.9×10^{-2}	0.723
	25	y= -0.048x + 2.604	4.8×10^{-2}	0.960
	35	y= -0.081x + 2.256	8.1×10^{-2}	0.815
	45	y= -0.139x + 1.799	1.4×10^{-1}	0.777

Table 4.48, 4.49 and 4.50 were found to be the linear with R^2 values in the range 0.785 – 0.932, 0.751 – 0.885 and 0.723 – 0.960 for Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. The first order reactions could be used to describe the changes of b* values. Therefore, Fig. 4.21, 4.22, 4.23 illustrate the temperature dependence of the reaction rate between ln *k* and (1/*T*) within different storage conditions such as Al bag with nitrogen, Al bag without nitrogen and clear plastic bag at four different temperatures, respectively.

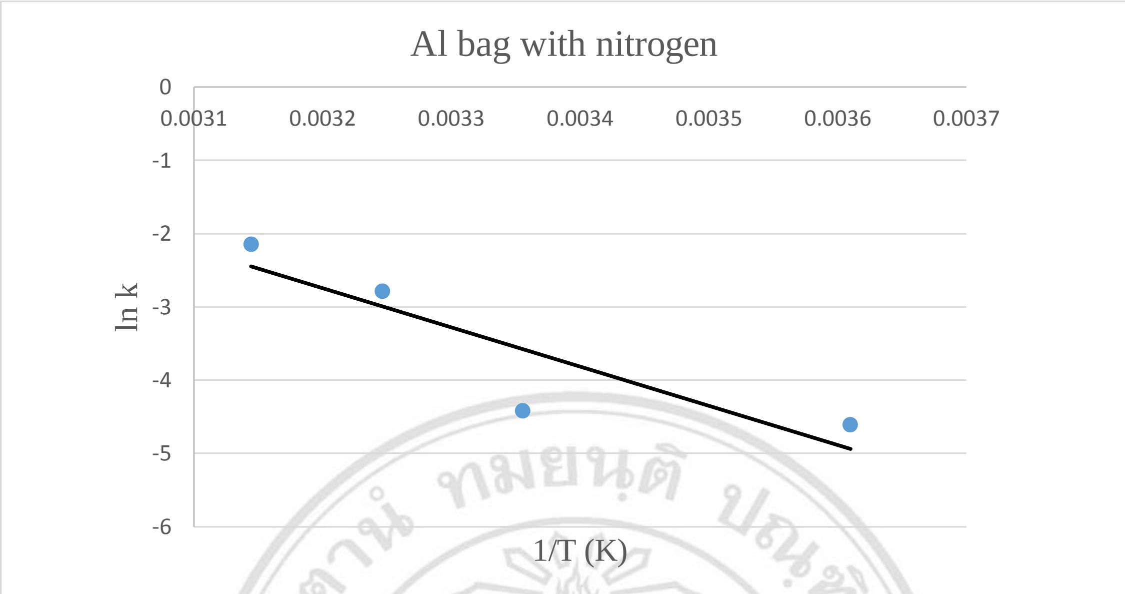

Figure 4.21 The relationship between the temperature and rate constant of b* value changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

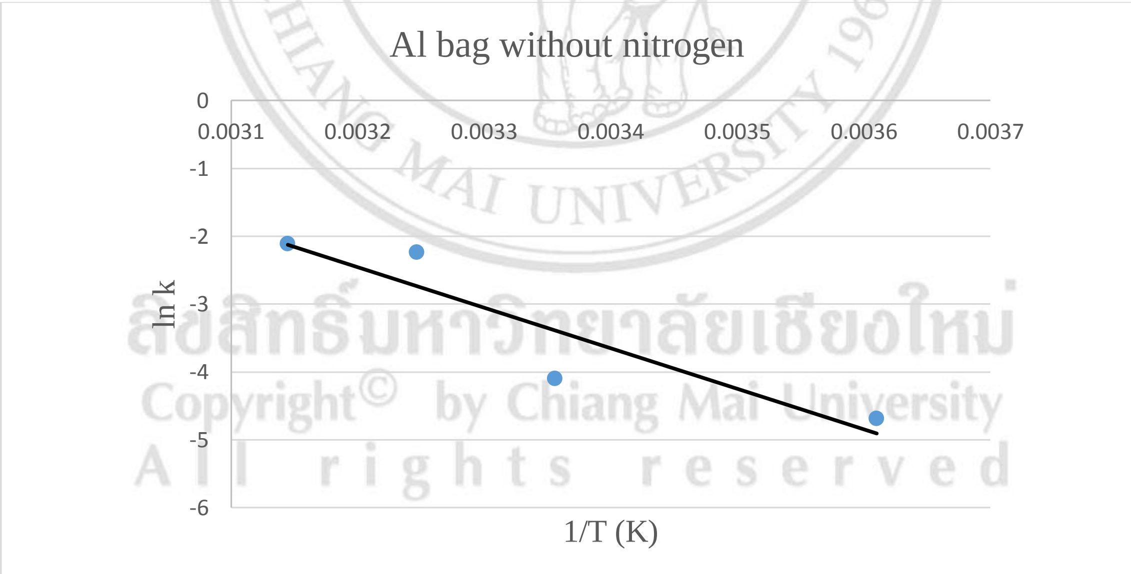

Figure 4.22 The relationship between the temperature and rate constant of b* value changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

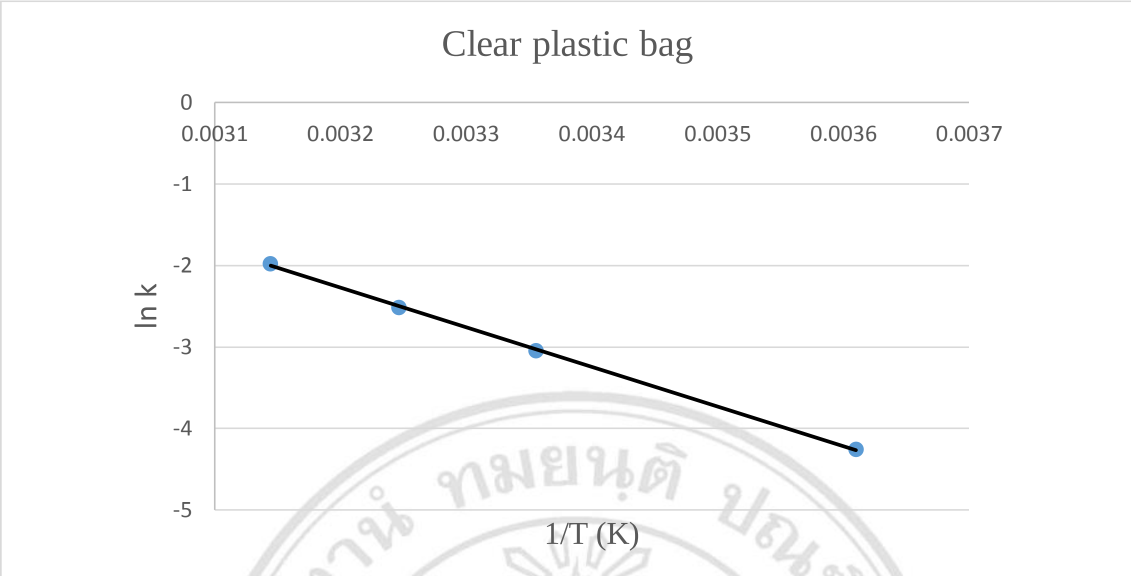

Figure 4.23 The relationship between the temperature and rate constant of b* value changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months according to Arrhenius equation.

Fig. 4.21, 4.22 and 4.23 show the rate constant of b* value changes and the regression equations were created from these figures. To estimate the effect of temperature on the reaction rate of color changes in b* values, values of *k* were estimated at different temperatures and ln *k* was plotted against the term of 1/*T* in a semilog graph. A straight line was obtained with a slope of - E_a/R from which the activation energy is calculated (Table 4.51).

Table 4.51 Linear equation of the rate of color deterioration (b* value change) and activation energies (E_a) of IML products stored at 4, 25, 35 and 45°C during 6 months according Arrhenius equation.

Treatments	**Linear equations**	**R^2**	***E_a***
Al bag with Nitrogen	$\ln k = -5977\ (\frac{1}{T}) + 16.688$	0.855	49.69 kJ/mol
Al bag without Nitrogen	$\ln k = -5209\ (\frac{1}{T}) + 13.948$	0.756	43.31 kJ/mol
Clear plastic bag	$\ln k = -4249.4\ (\frac{1}{T}) + 11.311$	0.991	35.33 kJ/mol

Activation energy (E_a) could be an indirect quantitative means available to compare samples effectively. 49.69 kJ/ mol, 43.31 kJ/ mol and 35.33 kJ/ mol are the excess energy barrier in which b* value changes need to overcome to proceed to degradation of IML products packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. Wangcharoen (2009) reported that the activation energy could be found about 48.1 kJ/ mol in which b* value changes during dried longan aril processing with using osmotic dehydration by sucrose. Homhuan (2013) studied that dried longan using with osmotic solution was shown with activation energy about 53.82 kJ/ mol to reduce the b* value of dried longan packed into aluminum foil laminated plastic bags with nitrogen while 47.51 kJ/ mol was the excess engery barrier in which color of dried longan packed into aluminum foil laminated plastic bags without nitrogen needs to reach at degradation. From Table 4.51, IML product packed in Al bag with nitrogen could be stored longer than the others.

4.4.2.3 The changes of texture of IML products during 6 months at different storage conditions

The changes of hardness of IML products were measured during 6 months at different conditions of storage. Hardness was likely increased during 6 months of storage period. A quality attribute hardness which increases during the storage time as shown in Fig. 4.24, 4.25 and 4.26 for IMLs packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag for zero order reactions, respectively. The linear plot illustrates that the rate of loss of color was constant throughout the storage period.

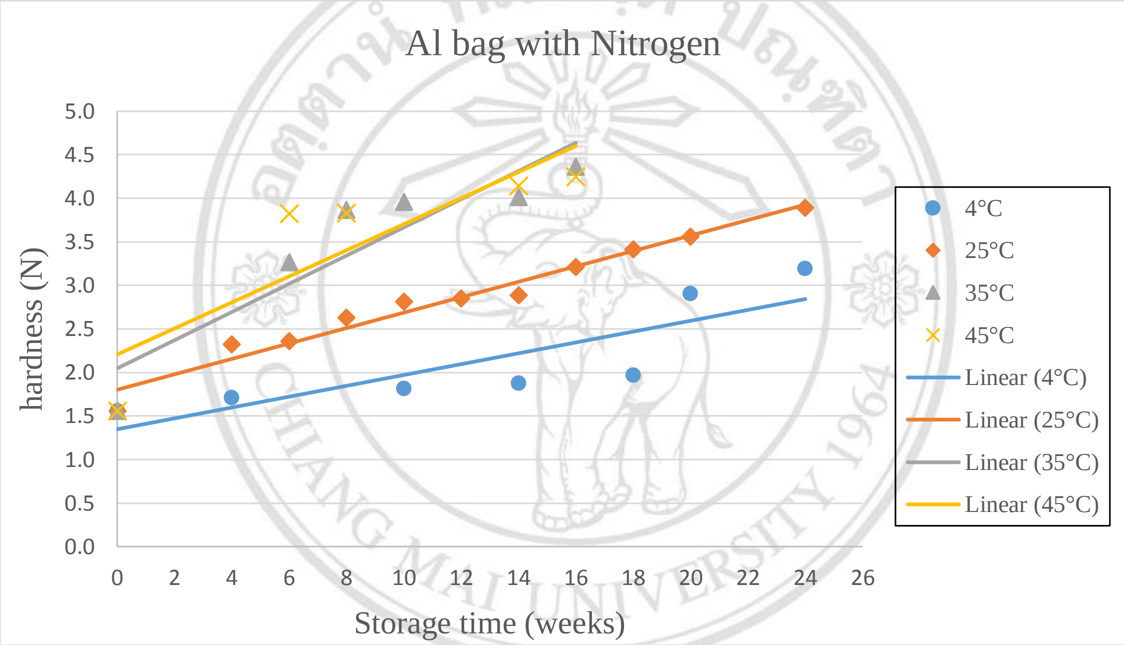

Figure 4.24 The hardness changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months (zero order reaction).

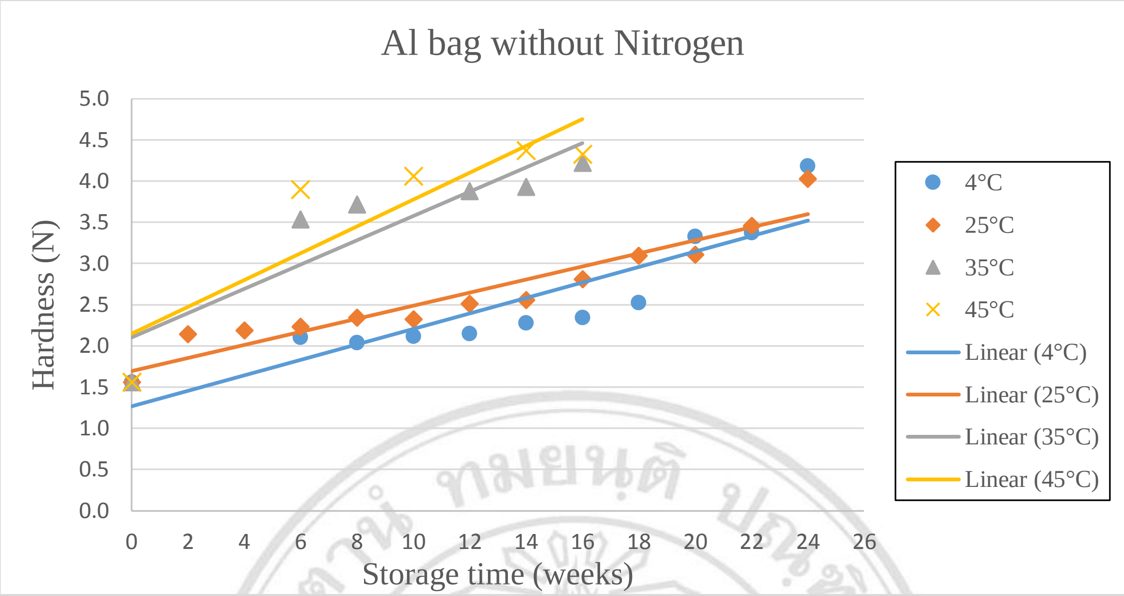

Figure 4.25 The hardness changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45ºC during 6 months (zero order reaction).

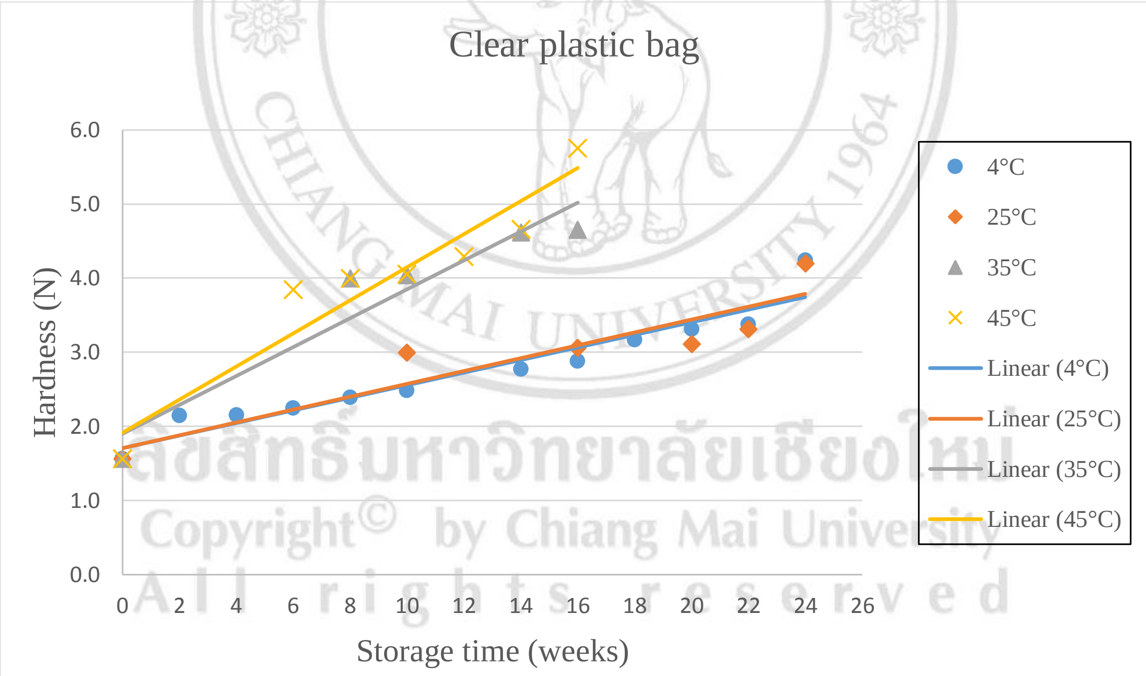

Figure 4.26 The hardness changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45ºC during 6 months (zero order reaction).

This exponential plot between textural attribute and storage time represented a first order reaction with n = 1, were shown in Fig. 4.27, 4.28 and 4.29 for IMLs packed into

Al bag with nitrogen, Al bag without nitrogen and clear plastic bag for zero order reactions, respectively. Table 4.52, 4.53 and 4.54 show the linear equations and constant rates of texture changes of IMLs during 6 months in which IMLs were packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag and stored at 4, 25, 35 and 45ºC, respectively. Arrhenius relationship was used to predict the influence of temperature on the reaction rate at each storage condition.

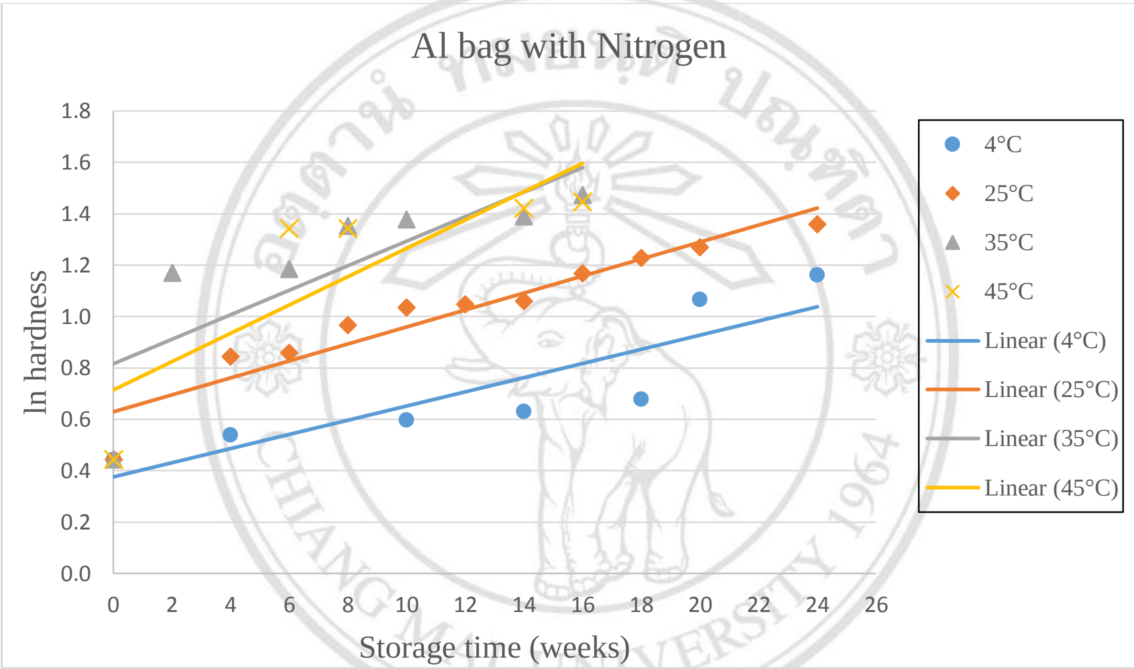

Figure 4.27 The hardness changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45ºC during 6 months (first order reaction).

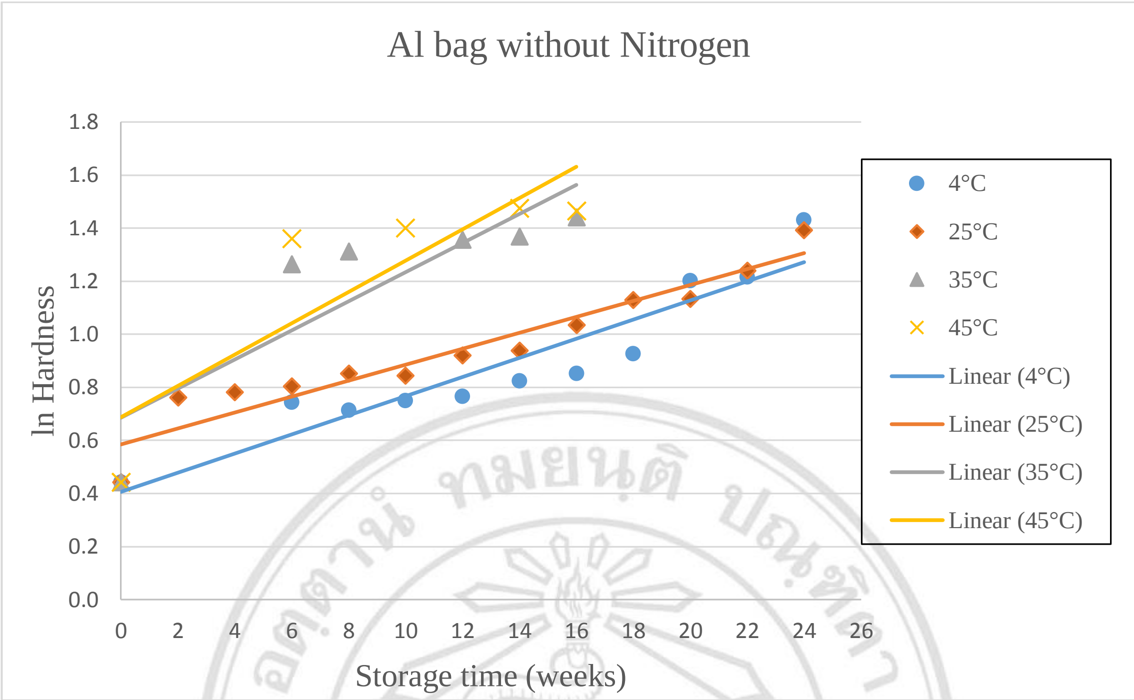

Figure 4.28 The hardness changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

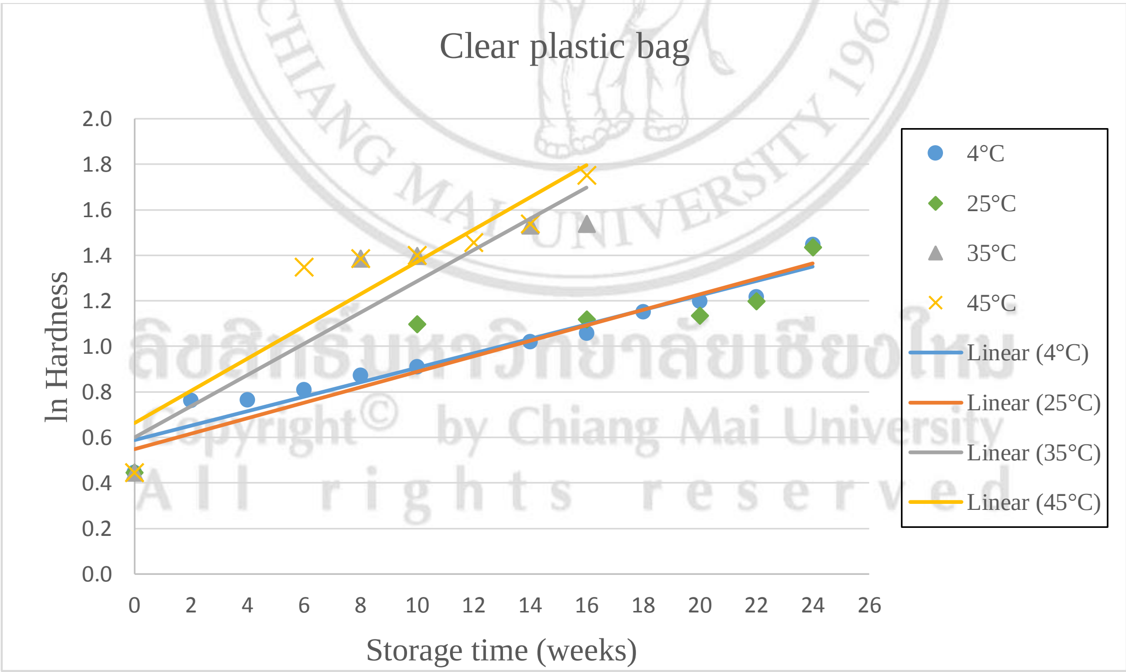

Figure 4.29 The hardness changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

Table 4.52, 4.53 and 4.54 were found to be the linear with R^2 values in the range 0.723 – 0.966, 0.783 – 0.905 and 0.843 – 0.920 for Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. And the zero order reactions could be used to describe the changes of texture. Therefore, Fig. 4.30, 4.31, 4.32 illustrate the temperature dependence of the reaction rate between ln *k* and (1/*T*) within different storage conditions such as Al bag with nitrogen, Al bag without nitrogen and clear plastic bag at four different temperatures, respectively.

Table 4.52 Linear equation and constant rate of hardness changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= 0.062x + 1.351	6.2×10^{-2}	0.723
	25	y= 0.088x + 1.804	8.8×10^{-2}	0.966
	35	y= 0.162x + 2.049	1.6×10^{-1}	0.840
	45	y= 0.150x + 2.206	1.5×10^{-1}	0.743
First order	4	y= 0.028x + 0.375	2.8×10^{-2}	0.776
	25	y= 0.033x + 0.629	3.3×10^{-2}	0.907
	35	y= 0.048x + 0.817	4.8×10^{-2}	0.643
	45	y= 0.055x + 0.715	5.5×10^{-1}	0.691

Table 4.53 Linear equation and constant rate of hardness changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= 0.094x + 1.270	9.4 x 10^{-2}	0.802
	25	y= 0.072x + 1.694	7.2 x 10^{-1}	0.905
	35	y= 0.148x + 2.099	1.5 x 10^{-1}	0.807
	45	y= 0.163x + 2.146	1.6 x 10^{-1}	0.783
First order	4	y= 0.036x + 0.406	3.6 x 10^{-2}	0.880
	25	y= 0.030x + 0.585	3.0 x 10^{-2}	0.917
	35	y= 0.055x + 0.686	5.5 x 10^{-2}	0.745
	45	y= 0.059x + 0.687	5.9 x 10^{-2}	0.736

Table 4.54 Linear equation and constant rate of hardness changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= 0.085x + 1.703	8.5 x 10^{-2}	0.920
	25	y= 0.087x + 1.707	8.7 x 10^{-2}	0.843
	35	y= 0.195x + 1.897	1.9 x 10^{-1}	0.911
	45	y= 0.224x + 1.912	2.2 x 10^{-1}	0.908
First order	4	y= 0.032x + 0.589	3.2 x 10^{-2}	0.933
	25	y= 0.034x + 0.548	3.4 x 10^{-2}	0.857
	35	y= 0.069x + 0.599	6.9 x 10^{-2}	0.860
	45	y= 0.071x + 0.664	7.1 x 10^{-1}	0.850

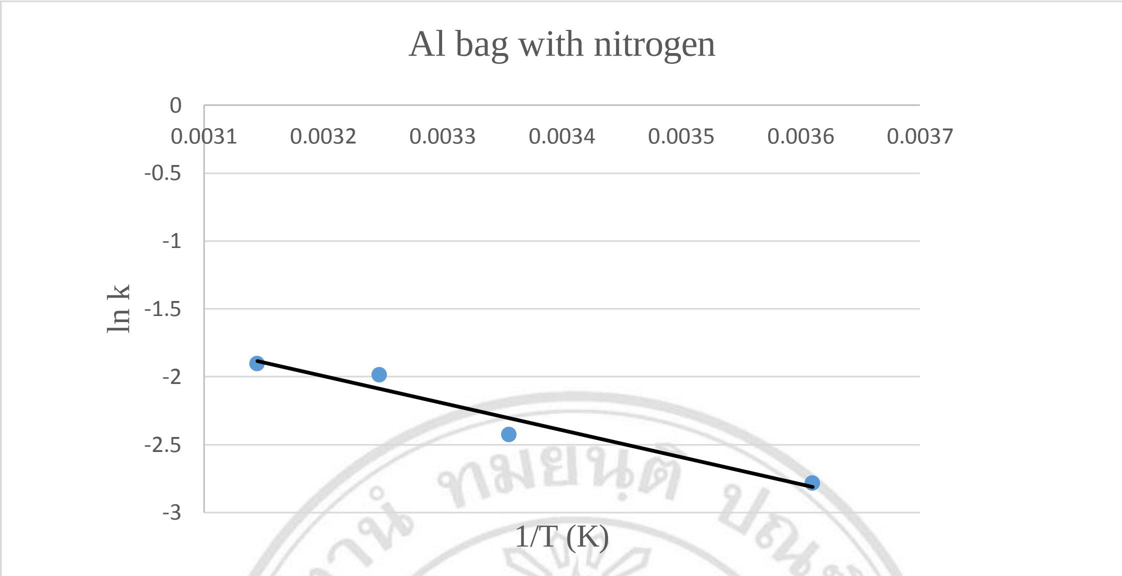

Figure 4.30 The relationship between the temperatures and rate constant of texture changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

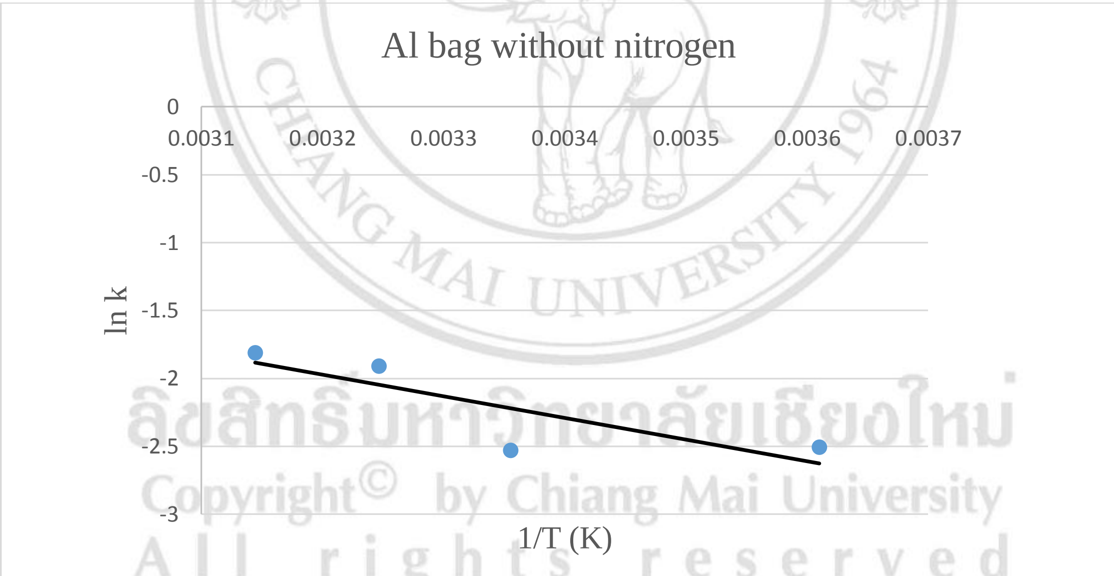

Figure 4.31 The relationship between the temperatures and rate constant of texture changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

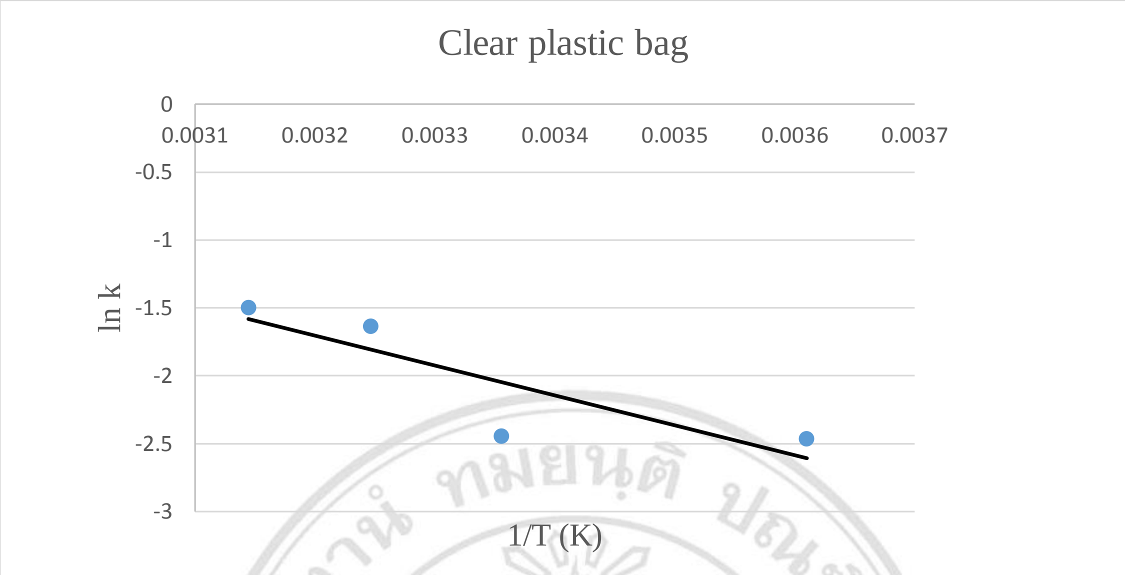

Figure 4.32 The relationship between the temperatures and rate constant of texture changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

Fig. 4.30, 4.31 and 4.32 show the rate constant of texture changes and the regression equations were created from these figures. To estimate the effect of temperature on the reaction rate of texture changes, values of *k* were estimated at different temperatures and ln *k* was plotted against the term of 1/*T* in a semilog graph. A straight line was obtained with a slope of - E_a/R from which the activation energy is calculated (Table 4.55).

Activation energy (E_a) could be an indirect quantitative means available to compare samples effectively. 16.56 kJ/ mol, 13.26 kJ/ mol and 18.34 kJ/ mol are the excess energy barrier in which texture changes need to overcome to proceed to degradation of IML products packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively.

Table 4.55 Linear equation of the rate of texture change and activation energies (E_a) of IML products stored at 4, 25, 35 and 45ºC during 6 months according Arrhenius equation.

Treatments	**Linear equations**	**R^2**	***E_a***
Al bag with Nitrogen	$\ln k = -1991.4 \left(\frac{1}{T}\right) + 4.3769$	0.948	16.56 kJ/mol
Al bag without Nitrogen	$\ln k = -1595.1 \left(\frac{1}{T}\right) + 3.1325$	0.700	13.26 kJ/mol
Clear plastic bag	$\ln k = -2206.3 \left(\frac{1}{T}\right) + 5.3571$	0.730	18.34 kJ/mol

4.4.2.4 The changes of color of IML products based on sensorial scores during 6 months at different storage conditions

The changes of sensorial scores of IML product's color were measured during 6 months at different conditions of storage. This change was likely decreased during 6 months of storage period. A sensory attribute which increased during the storage time as shown in Fig. 4.33, 4.34 and 4.35 for IMLs packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag for zero order reactions, respectively. The linear plot illustrates that the rate of loss of color was constant throughout the storage period.

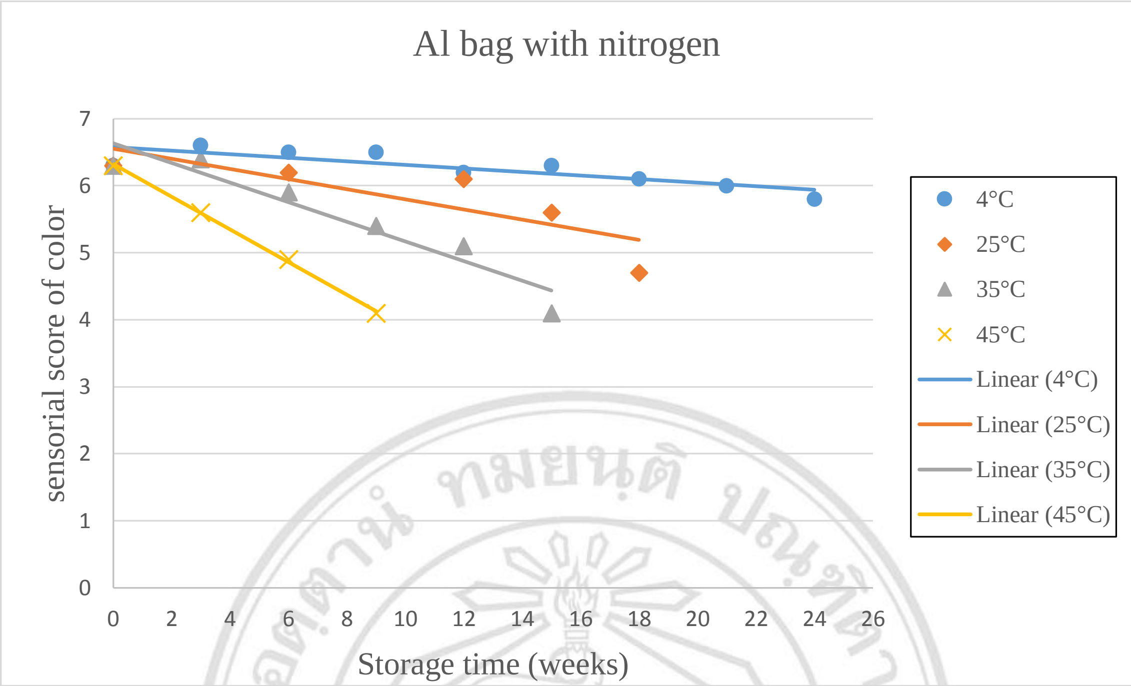

Figure 4.33 The sensorial scores of color of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45ºC during 6 months (zero order reaction).

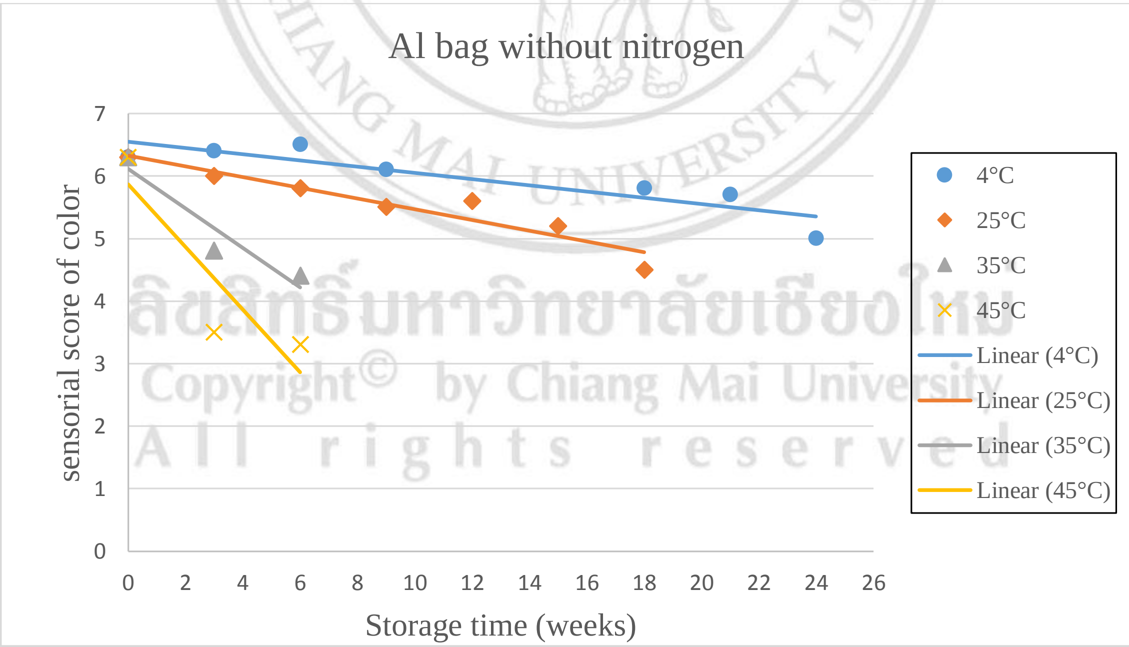

Figure 4.34 The sensorial scores of color of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45ºC during 6 months (zero order reaction).

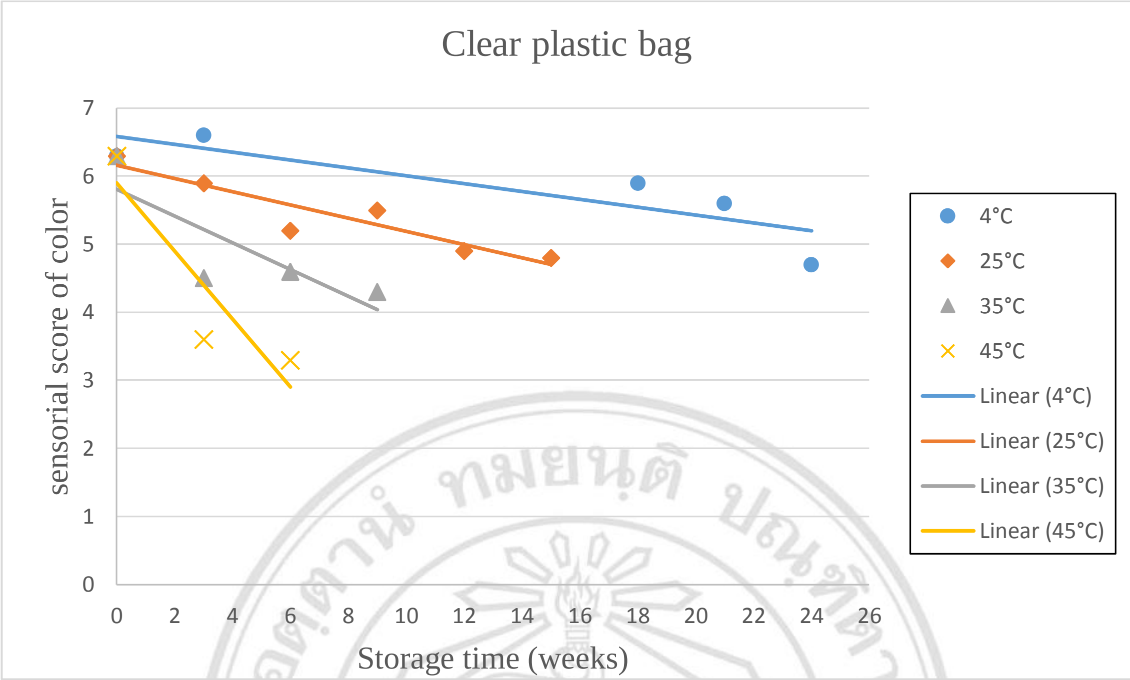

Figure 4.35 The sensorial scores of color of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months (zero order reaction).

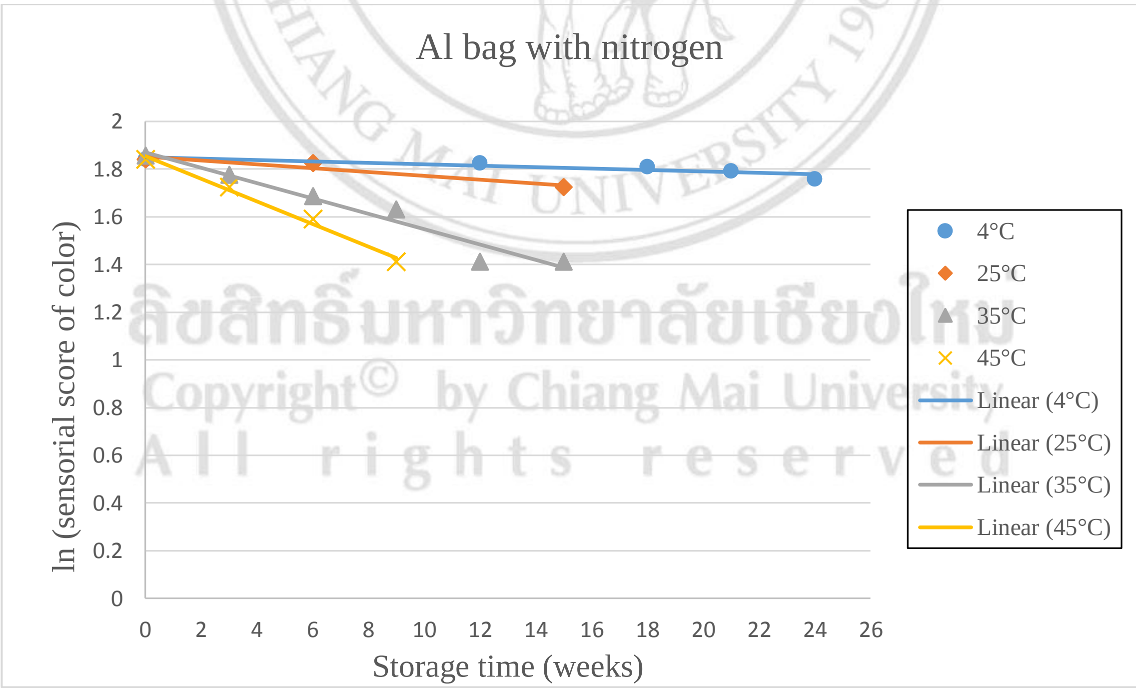

Figure 4.36 The sensorial scores of color of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

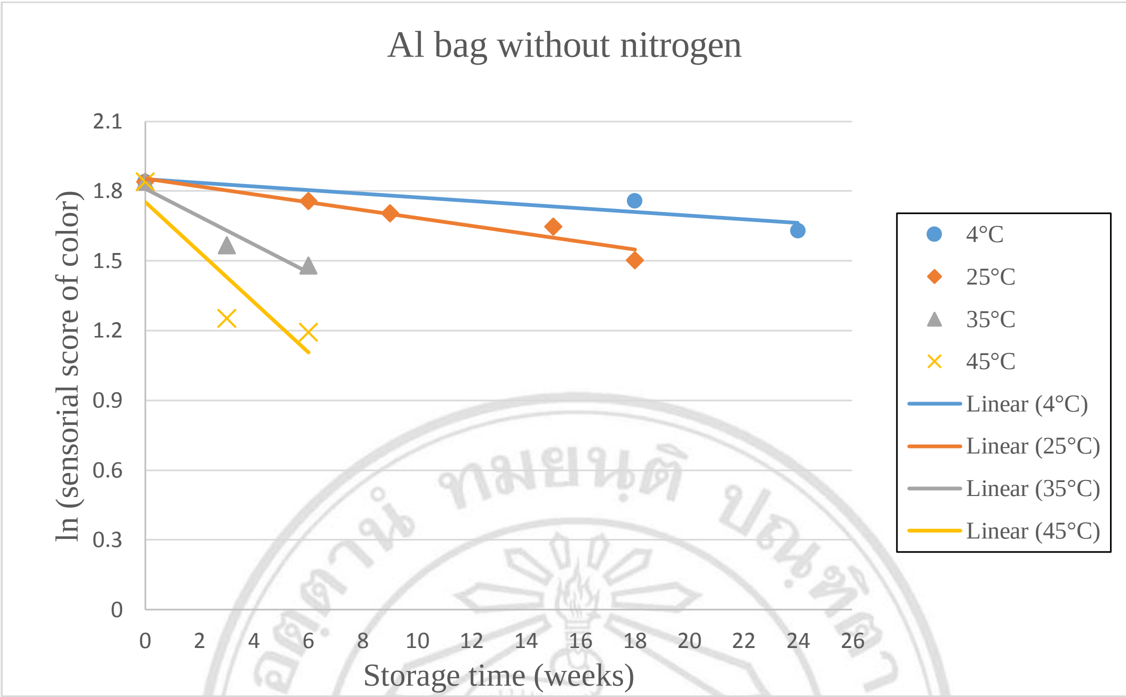

Figure 4.37 The sensorial scores of color of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

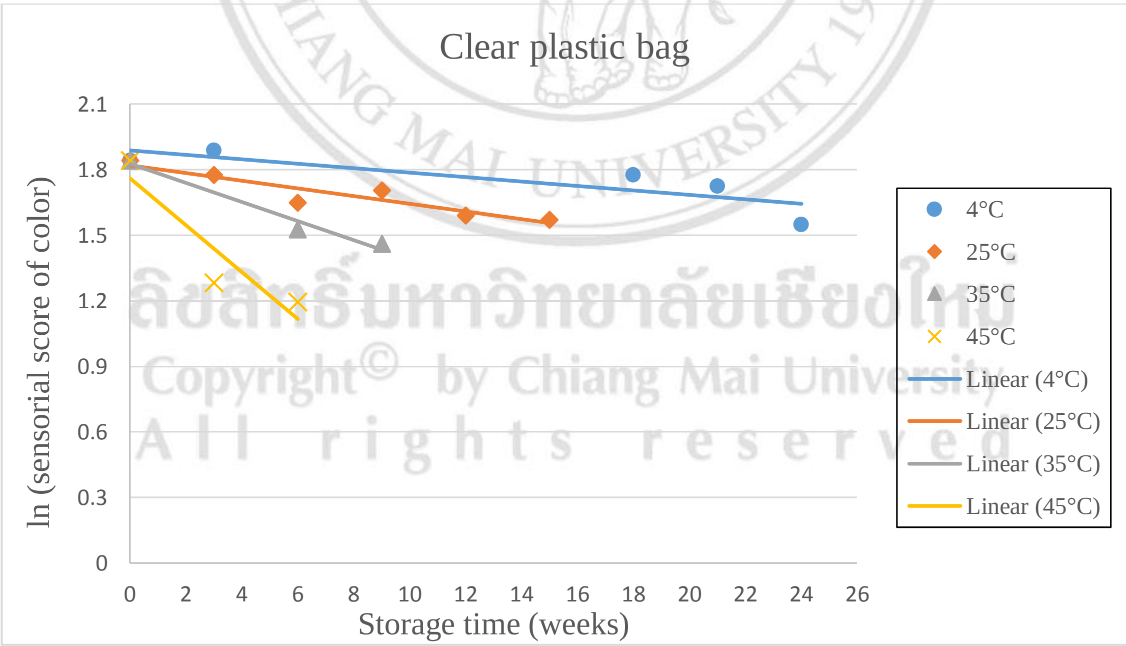

Figure 4.38 The sensorial scores of color of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months (first order reaction).

This exponential plot between color sensorial scores and storage time represented a first order reaction with n = 1, were shown in Fig. 4.36, 4.37 and 4.38 for IMLs packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag for zero order reactions, respectively. Table 4.56, 4.57 and 4.58 show the linear equations and constant rates of color sensorial changes of IMLs during 6 months in which IMLs were packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag and stored at 4, 25, 35 and 45°C, respectively. Arrhenius relationship was used to predict the influence of temperature on the reaction rate at each storage condition.

Table 4.56, 4.57 and 4.58 were found to be the linear with R^2 values in the range 0.705 – 0.991, 0.784 – 0.919 and 0.716 – 0.972 for Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. The first order reactions could be used to describe the changes of color sensorial scores. Therefore, Fig. 4.39, 4.40, 4.41 illustrate the temperature dependence of the reaction rate between ln *k* and (1/*T*) within different storage conditions such as Al bag with nitrogen, Al bag without nitrogen and clear plastic bag at four different temperatures, respectively.

Table 4.56 Linear equation and constant rate of sensorial score changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.027x + 6.576	2.7×10^{-2}	0.708
	25	y= -0.076x + 6.551	7.6×10^{-2}	0.682
	35	y= -0.147x + 6.633	1.5×10^{-1}	0.908
	45	y= -0.243x + 6.320	2.4×10^{-1}	0.999
First order	4	y= -0.003x + 1.850	0.3×10^{-2}	0.808
	25	y= -0.008x + 1.853	0.8×10^{-2}	0.922
	35	y= -0.032x + 1.869	3.2×10^{-2}	0.950
	45	y= -0.047x + 1.854	4.7×10^{-2}	0.991

Table 4.57 Linear equation and constant rate of sensorial score changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.050x + 6.550	5.0×10^{-2}	0.810
	25	y= -0.086x + 6.329	8.6×10^{-1}	0.900
	35	y= -0.317x + 6.117	3.2×10^{-1}	0.899
	45	y= -0.500x + 5.567	5.0×10^{-1}	0.799
First order	4	y= -0.008x + 1.852	0.8×10^{-2}	0.844
	25	y= -0.017x + 1.854	1.7×10^{-2}	0.928
	35	y= -0.060x + 1.810	6.0×10^{-2}	0.919
	45	y= -0.108x + 1.752	1.1×10^{-1}	0.818

Table 4.58 Linear equation and constant rate of sensorial score changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45°C during 6 months.

Reaction	Temperatures (°C)	Linear equation	Constant rate (k)	R^2
Zero order	4	y= -0.058x + 6.584	5.8×10^{-2}	0.747
	25	y= -0.097x + 6.162	9.7×10^{-2}	0.868
	35	y= -0.197x + 5.810	1.9×10^{-1}	0.678
	45	y= -0.500x + 5.900	5.0×10^{-1}	0.824
First order	4	y= -0.010x + 1.889	1.0×10^{-2}	0.716
	25	y= -0.018x + 1.821	1.8×10^{-2}	0.873
	35	y= -0.044x + 1.828	4.4×10^{-2}	0.972
	45	y= -0.108x + 1.762	1.1×10^{-1}	0.859

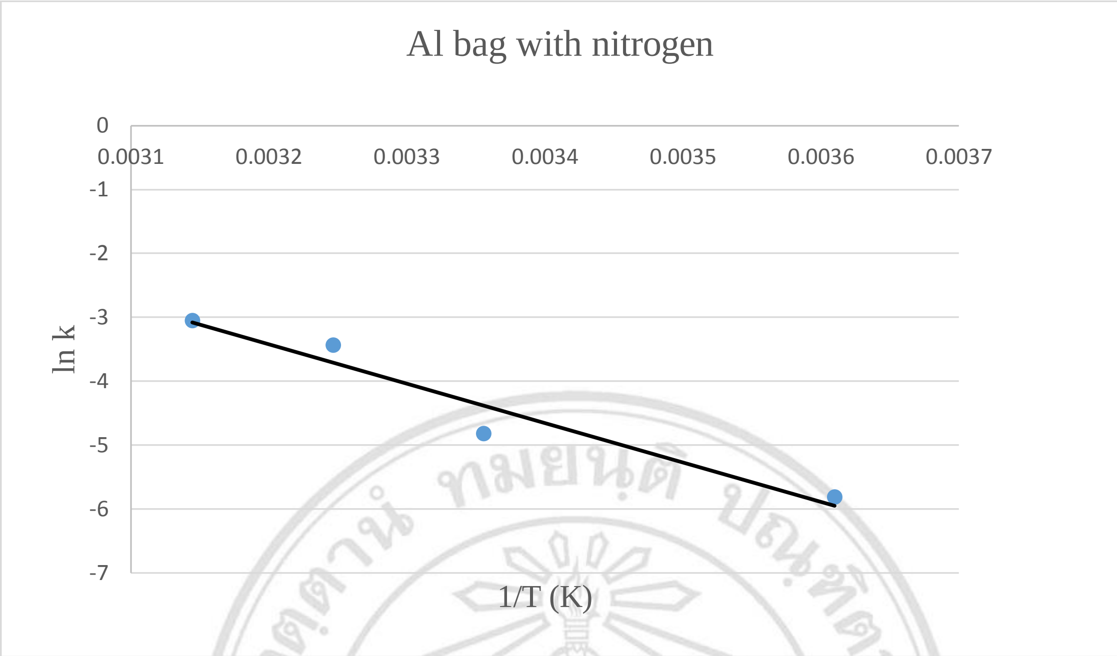

Figure 4.39 The relationship between the temperatures and rate constant of sensorial score changes of IML products packed into Al bag with nitrogen and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

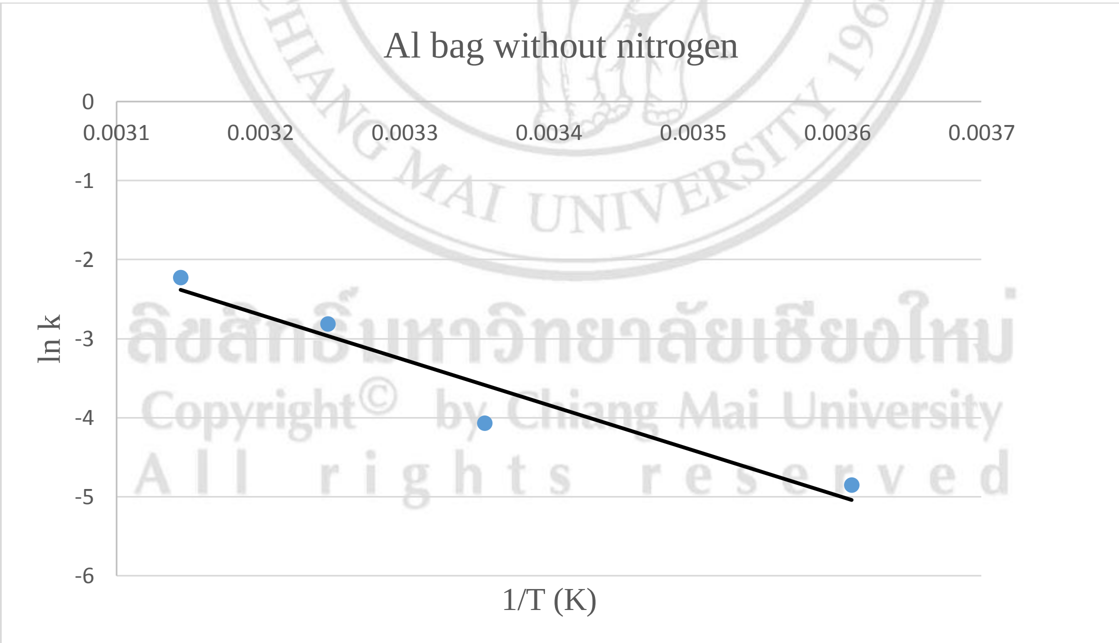

Figure 4.40 The relationship between the temperatures and rate constant of sensorial score changes of IML products packed into Al bag without nitrogen and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

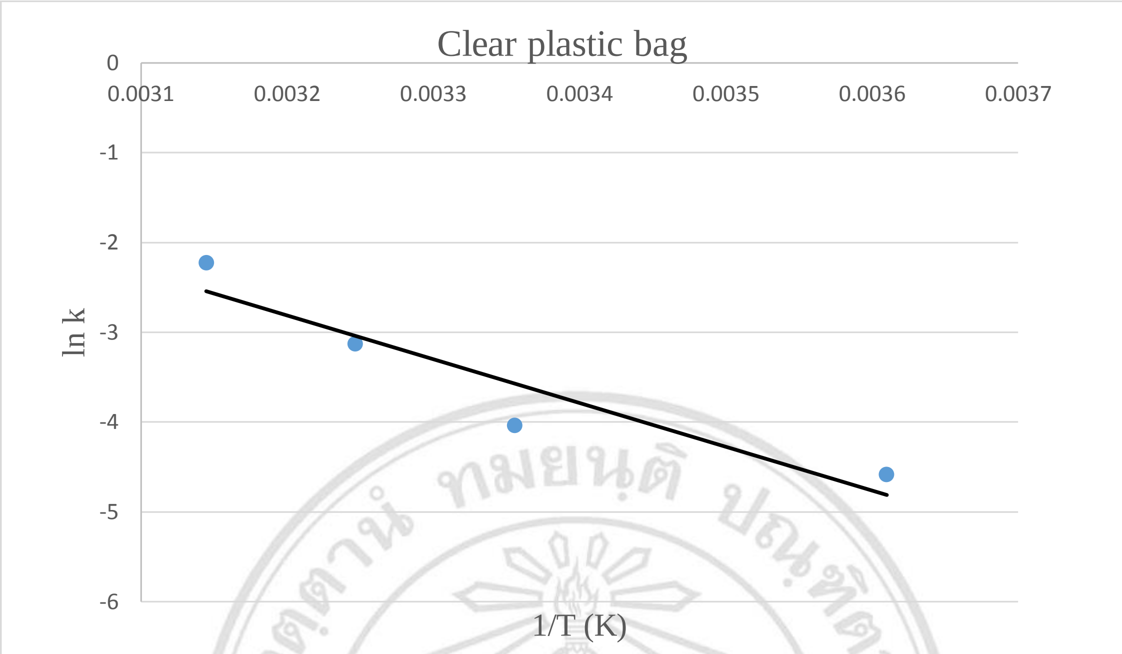

Figure 4.41 The relationship between the temperatures and rate constant of sensorial score changes of IML products packed into clear plastic bag and stored at 4, 25, 35 and 45ºC during 6 months according to Arrhenius equation.

Fig. 4.39, 4.40 and 4.41 show the rate constant of sensorial scores of color changes and the regression equations were created from these figures. To estimate the effect of temperature on the reaction rate of changes in color sensorial score, values of k were estimated at different temperatures and ln k was plotted against the term of $1/T$ in a semilog graph. A straight line was obtained with a slope of - E_a/R from which the activation energy is calculated (Table 4.59).

Activation energy (E_a) could be an indirect quantitative means available to compare samples effectively. 51.26 kJ/ mol, 47.57 kJ/ mol and 40.51 kJ/ mol are the excess energy barrier in which color acceptability changes need to overcome to proceed to degradation of IML products packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively. From Table 4.59, IML product packed in Al bag with nitrogen could be stored longer than the others.

Table 4.59 Linear equation of the rate of sensorial score changes and activation energies (E_a) of IML products stored at 4, 25, 35 and 45ºC during 6 months according Arrhenius equation.

Treatments	**Linear equations**	$\mathbf{R^2}$	$\boldsymbol{E_a}$
Al bag with Nitrogen	ln k = -6166.3 ($\frac{1}{T}$) + 16.313	0.942	51.26 kJ/mol
Al bag without Nitrogen	ln k = -5721.6 ($\frac{1}{T}$) + 16.111	0.925	47.57 kJ/mol
Clear plastic bag	ln k = -4872.7 ($\frac{1}{T}$) + 12.778	0.885	40.51 kJ/mol

The regression equations can be used to estimate the shelf life of IML products by determining k value at different desired temperatures, representing in the Arrhenius equation. The sensorial scores of color was found to be 6.3 at the beginning of storage and the reject points were 4.7, 4.8 and 4.9 for IML products packed in Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, respectively (the results from color sensory evaluation which slightly below 5.0 at 25ºC at week 18 for Al bag with nitrogen, Al bag without nitrogen and week 12 for clear plastic bag were shown in Table 4.40, 4.41 and 4.42).

$$ln\ \frac{A_t}{A_o} = -kt$$

Where A_o represents initial value of a quality attribute

A_t is the amount of that attribute left after time t

k is rate constant

Table 4.60 Predicted shelf life of intermediate moisture longan at 4ºC, 25ºC, 35ºC and 45ºC in Al bag with nitrogen, Al bag without nitrogen and clear plastic bag.

Treatments	Storage temperature (ºC)	Sensory evaluation
		Color
Al bag with nitrogen	**4**	97.66
	25	36.62
	35	9.16
	45	6.23
Al bag without nitrogen	**4**	34.00
	25	16.00
	35	4.53
	45	2.52
Clear plastic bag	**4**	25.13
	25	13.96
	35	5.71
	45	2.33

Table 4.60 shows the predicted storage time of IML products at different temperatures using sensory evaluation as an index. It can be found that the IML product, which was packed into Al bag with nitrogen at 4ºC, can be stored for 97.66 weeks. Next, the IML product was packed into Al bag without nitrogen at 4ºC, can be stored for 34 weeks. Finally, the IML product was packed into clear plastic bag at 4ºC, can be stored for 25.13 weeks.

At a temperature of 25ºC, the IML products were packed into Al bag with nitrogen, Al bag without nitrogen and clear plastic bag, can be stored for 36.62 weeks, 16 weeks and 13.96 weeks, respectively.

The IML products, which were packed into Al bag with nitrogen and stored at 35°C and 45°C, can be kept individually for 9.16 weeks, 6.23 weeks. Moreover, the IML products, which were stored at 35°C and 45°C into Al bags without nitrogen, can be put in storage for 4.53 weeks, 2.52 weeks, respectively. Besides, the IML products packed in clear plastic bags can be stored for 5.71 weeks at 35°C and 2.33 weeks at 45°C.

From the results of this study, the stable shelf life of IML products packed into three packages at 4°C and would be followed was at 25°C could provide good quality of color and high scores of sensory acceptability. The IML's shelf life can be reached to 37 weeks, 16 weeks, 14 weeks for Al bag with nitrogen, al bag without nitrogen and clear plastic bag when they were stored at 25°C, respectively. The previous studies reported the storage of osmotically dehydrated papaya products remained stable up to six months at the ambient temperature (Ahemed and Choudhary, 1995) and banana products were stored up to one year or more depending on the storage conditions and packaging materials used (Bongirwar and Sreenivasan, 1977). Furthermore, Illeperuma and Jayathunge (2001) studied that the intermediate moisture "Kolikttu" banana could be packaged in pouches made out of Al foil laminated with low – density polyethylene and stored for 8 months without any change in water activity and product color.