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The Effect of Temperature and Cooking Time on Physical Stability and Quality of Kepundung Syrup

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Abstract: Kepundung is a local fruit that grows almost on all island in Indonesia, the used of kepundung can be processed into fruit syrup. This research aims to determine the effect of temperature and cooking time on the physical stability and quality of kepundung syrup. This research began by making syrup made from kepundung fruit. The method used in this research is a factorial Completely Randomized Design method with two factors, that is cooking temperature (A): (80°C, 90°C, and 100°C) and cooking time (B): (20, 30, and 40 minute). The parameters tested in this research were color index stability (°Hue), pH, viscosity, organoleptic testing for 8 weeks, and thermal degradation kinetics. The results of the research showed that cooking temperature had a very significantly different effect (P<0.01) on the stability of the color index, pH, and viscosity. The best treatment for kepundung syrup is A3B3 (temperature 100°C and cooking time 40 minutes). Based on the determination of the kinetic ordo of thermal degradation, the color index R^2 is closest to 1 at ordo 0 and in the calculation of Ea, ordo 0 is chosen with smaller Ea value. Based on determining ordo of thermal degradation kinetics, pH R^2 closest to 1 at ordo 0 and in the calculation of Ea, ordo 1 is chosen with smaller Ea. Based on determining ordo of thermal degradation viscosity R^2 is closest to 1 at ordo 1 and in the calculation of Ea, ordo 0 is chosen with smaller Ea.

Keywords: Kepundung; Stability; Syrup

Introduction

Kepundung is a local fruit that grows almost on all island in Indonesia. But, now it can find just only on few islands cause kepundung not much like of its sour taste. Not many people use kepundung fruit so they prefer to plant rambutan, nangka, kelengkeng, duku, durian, and other primadonna fruit. Other than eating it straight away as fresh fruit, kepundung fruit can also processed into pickles, fermented to be wine, or syrup.

Syrup or concentrated fruit juice is a processed product in the form of liquid from the destruction of fruit flesh followed by a concentration process, either by normal boiling or by other methods such as evaporation using vacuum and so on (Margono, 2000). The process of making fruit syrup goes trough extraction, mixing and cooking. Temperature and cooking time to make snake fruit syrup at a temperature of ^{0}C for 15 minutes (Fahrul, Yulia, & Katsum, 2020). Temperature and cooking time to make starfruit syrup, at a temperature of 100 ^{0}C for ± 10 minutes (Fitri, Harun, & Johan, 2017). Process to make fruit syrup stopped when the texture thickens.

Based on length, stability tests are divided into two, namely short-term (accelerated) and long-term (real time study) stability tests. Types of stability testing for medicinal, cosmetic and food or beverage preparations include stability; physics, chemistry, and microbiology (Rismana, Idah, Bunga, Yunianto, & Erna, 2015). Physical stability is evaluating changes in the physical properties of a product depending on the length (storage period) (Vadas, 2010). The chemical stability of a drug is the length of time a drug lasts maintains its chemical integrity and potency as listed below label within the specified length of time (Attwood & Florence, 2008).

The research included making kepundung fruit syrup by paying attention to temperature and cooking time then testing its physical stability by testing color,

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Color Index (°*Hue*)

pH and viscosity; and also quality degradation kinetics test. The variable used for temperature is starting at 80 ^{0}C for every 10^{0}C increase up to 100 ^{0}C. And the cooking time (heating) starts from 20 minutes, 30 minutes, dan 40 minutes.

Method

The ingredients used in this research include kepundung, sugar, CMC, citric acid, sodium benzoate, and distilled water. Tools used in this research is filters, scales, thermometer, stopwatch, erlenmeyer flasks, beaker glass, separating funnels, measuring cups, measuring flask, pH meter, viscometer and chromameter.

Physical Stability Test

Syrup stability testing was carried out based on experiments by Djajadisastra, Mun'im, & Dessy (2009) with storing the resulting syrup in a climatic chamber at a temperature 40 ^{0}C for 8 weeks and observing physical changes every 2 weeks. The physical changes observed were kepundung fruit syrup color, pH and viscosity.

Quality Analysis

The Quality of kepundung fruit syrup is seen based on its physical changes from thermal degradation. The Arrhenius and Ball kinetic model is used as follows :

Ordo -n $: \frac{dC}{dt} = -kC^n$ (1)

Ordo 0 $: C - C_0 = -kt$ (2)

Ordo 1 $: ln\left(\frac{C}{C_0}\right) = -kt$ (3)

Where C is the concentration of physical changes at a certain time t; k is the reaction rate constan (concentration unit $1 - n/time$) (1/minute).

$$D = \frac{t}{log\left(\frac{N_0}{N_t}\right)} \quad (4)$$

$$Z = \frac{T_2 - T_1}{\log\left(\frac{DT}{D_0}\right)} \quad (5)$$

$$k = \frac{\ln 10}{D} = \frac{2{,}303}{D} \quad (6)$$

$$\ln k = \ln k_0 - (Ea/R)(1/T) \quad (7)$$

Result and Discussion

Physical Characteristics of Kepundung syrup

Color Index (°Hue)

The effect of interaction of temperature and cooking time on the stability of the color index kepundung syrup

Interaction relationship between temperature and cooking time and color index stability can be seen in Figure 1.

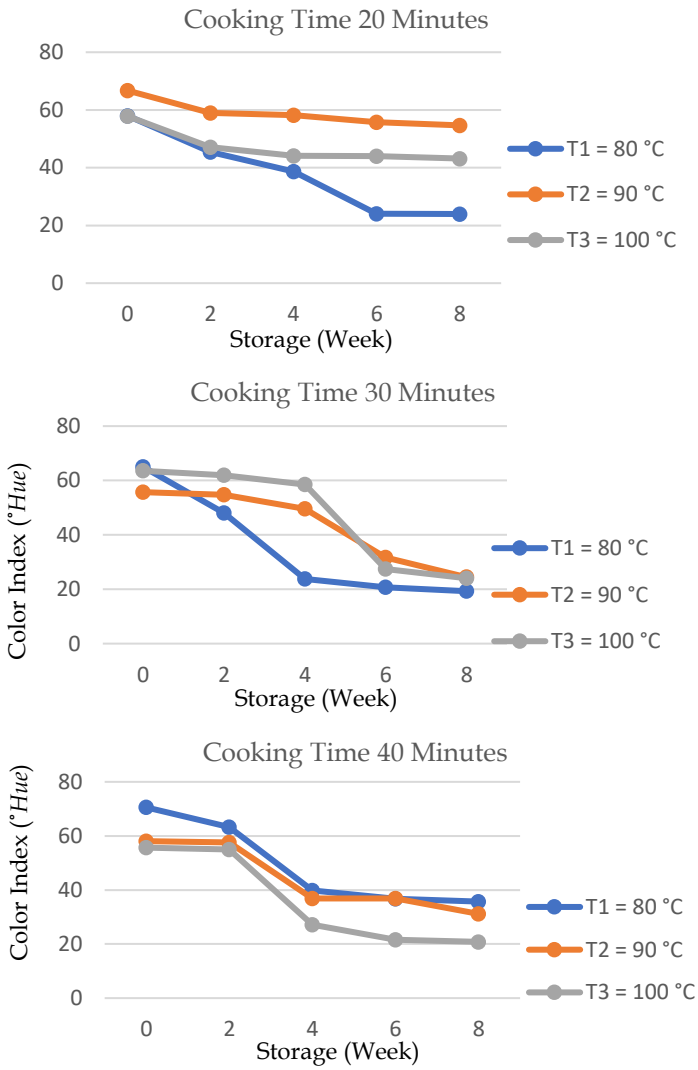

Figure 1. Interaction relationship between temperature and cooking time on the color index stability of kepundung syrup for 8 weeks storage.

Figure 1 showed kepundung syrup with 90°C temperature treatment and 20 minutes cooking time has a stable color index value. At this reasearch, color index kepundung syrup resulting 19,28-70,56 (red up to reddish yellow), while the commercial syrup on the market, namely Pohon Pinang syrup with dutch eggplant flavor produces a color ranging from 1,89-318,99 (purpel red to purpel). The color of the fruit syrup product will follow the natural color of the fruit used in cooking the syrup (Susanti, 2016).

pH

The effect of interaction of temperature and cooking time on the stability of pH kepundung syrup

Interaction relationship between temperature and cooking time on pH stability can be seen in Figure 2.

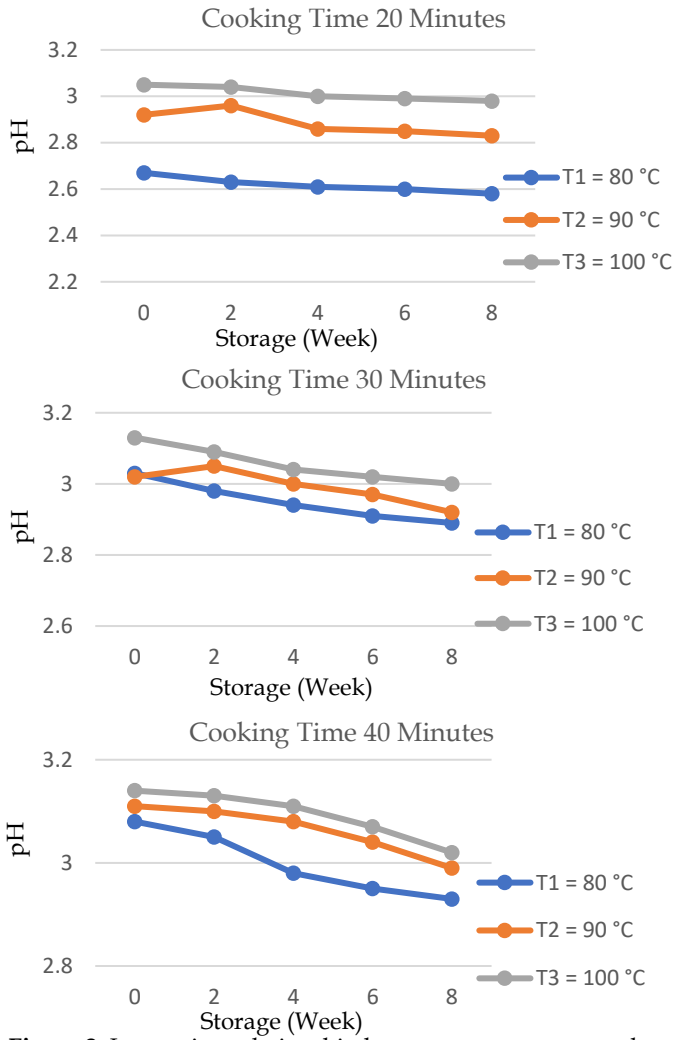

Figure 2. Interaction relationship between temperature and cooking time on the pH stability of kepundung syrup for 8 weeks storage.

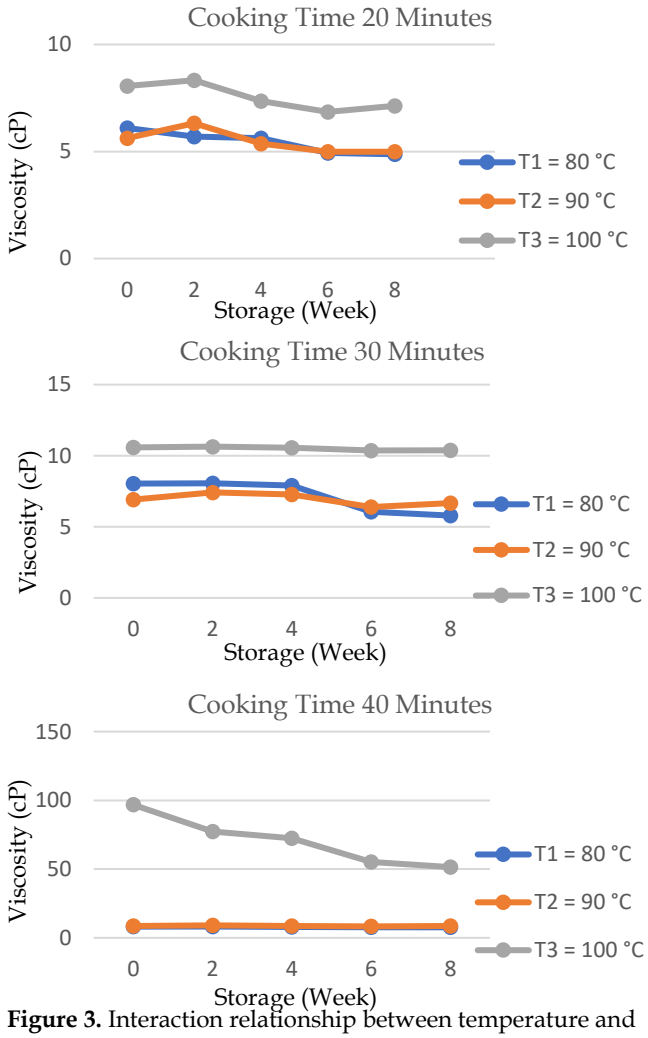

Figure 3. Interaction relationship between temperature and cooking time on the viscosity stability of kepundung syrup for 8 weeks storage.

In this study, pH value of kepundung syrup obtained was in range of 2,81– 3,10. This is not much different from the results of Dari & Junita (2020) research, reagarding the physical and sensory characteristics of pedada fruit juice drinks which have a pH ranging from 2,95 - 3,20. And can match the pH of commercial Pohon Pinang syrup with dutch eggplant flavor ranging from 2,9-2,94. The acidic condition produced in the syrup is caused by the raw material in cooking the syrup that is kepundung fruit. According Silvia & Oktaviani (2018), one of the factors that influences the acidity level is the total acid content in the material.

Viscosity

The effect of interaction of temperature and cooking time on the stability of viscosity kepundung syrup

Interaction relationship temperature and cooking time on viscosity stability can be seen in Figure 3.

During storage the viscosity degreases because the CMC undergoes oxidation due to the influence of air, where oxygen molecules from the air can cause damage to the CMC colloidal disperse system by breaking off the carboxyl groups, so that the viscosity of the syrup decreases (Murrukmihadi, Wahyuono, Marchaban, & Martono, 2011). Confirm by Winarno (2004), viscosity decreases during storage because many macromolecular compounds are broken down into micromolecular compound. Mold degrades the macromolecules that make up the material into smaller fractions. During the storage process, sucrose is broken down into simpler sugar compounds.

Thermal Degradation Kinetics

Color Index (°Hue)

Testing the color index (°*Hue*) with different temperature conditions, at temperature 80°C, 90°C, and 100°C, then the parameter values were plotted against different cooking times at 20, 30, and 40 minutes.

Thermal degradation kinetics is used to reduce the quality of kepundung syrup. Determination thermal degradation kinetics includes calculation parameter k (1/menit), D (menit), Z (°C), dan Ea (kJ/mol.K).

Determination of the reaction order is carried out by plotting data from color observations during cooking at a pre-conditioned temperature. Ordo 0 reaction are obtained from the linear regression equation plot between sample color and cooking time. Ordo 1 reactions are obtained from the liniear regression equation plot between in sample color and cooking time. The kinetics of thermal degradation of ordo 0 and ordo 1 color indices can be seen in Figure 4. Calculations of the D, Z, and activation energy of color indices at ordo 0 and ordo 1 can be seen in Table 1.

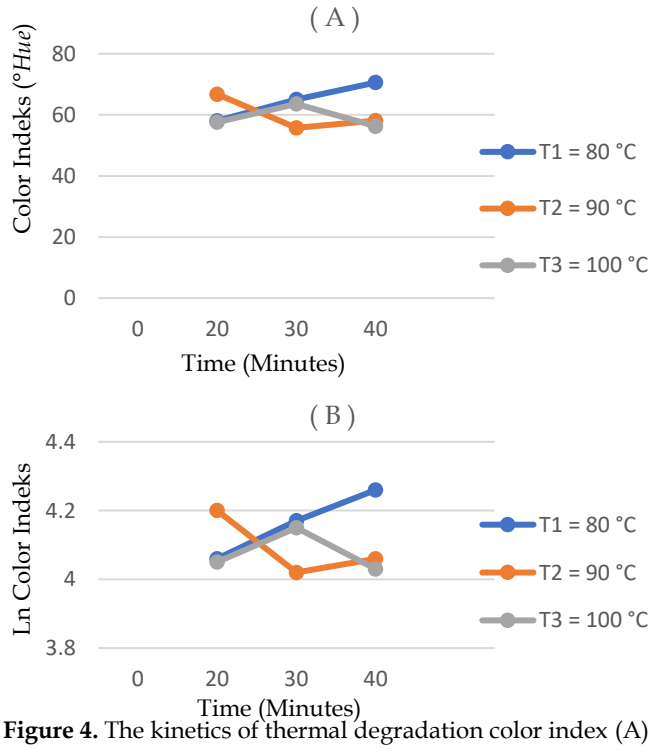

Figure 4. The kinetics of thermal degradation color index (A) Ordo 0 and (B) Ordo 1

Figure 4 shows that R^2 is closest to 1 at ordo 0, so that kinetics of thermal degradation of kepundung syrup color index uses ordo 0 with a R^2 of 0,0247- 0,996. There was an increase in the color index of kepundung syrup at temperature 80°C, mean while at temperature 90°C and 100°C there was a decrease in the color index.

Based on Table 1, the largest D value is at ordo 1, temperature 100 °C at 2093,6364 minute and the smallest D value is at ordo 0 temperature 80 °C at 3,6789 minute. The greater D value indicates the higher heat resistance of the color index at certain temperature. According to Herdiana, Utami, & Anandito (2014), determining D value is to state the length of heat treatment required at a certain temperature to reduce 90% or one tenth of the initial value. The curve for determining Z value of thermal degradation of the color index of kepundung syrup can be seen in Figure 5. The curve for determining the activation energy of thermal degradation of the color index of kepundung syrup during cooking can be seen in Figure 6.

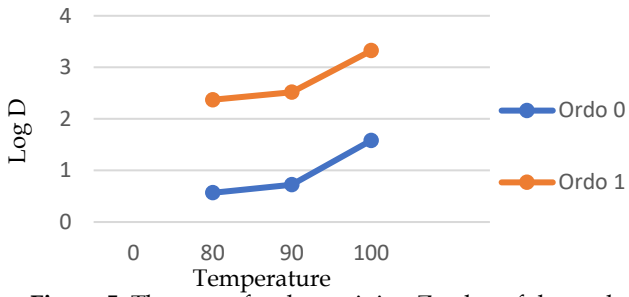

Figure 5. The curve for determining Z value of thermal degradation of the color index of kepundung syrup

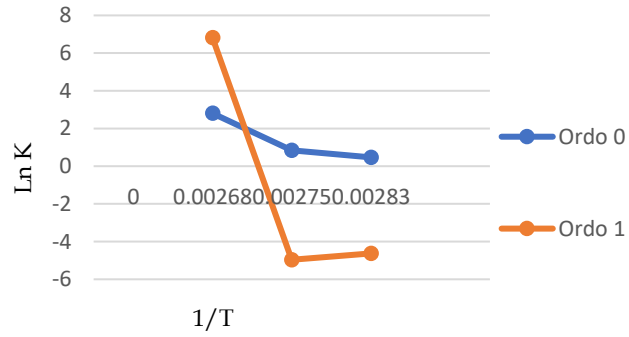

Figure 6. The curve for determining the activity energy of thermal degradation of the color index of kepundung syrup during cooking

Based on Table 1, k value becomes smaller as the cooking temperature increase. The Z value of ordo 0 is smaller than ordo 1. Likewise with the activity energy (Ea) obtained 9,7108 J/mol in ordo 0 and 47,5394 J/mol in ordo 1. That activity energy means that the minimum amount of energy required by molecules in kepundung syrup to reduce the value of color index which is at ordo 0. The lower Ea value, the easier it is for decrease to occur. Swadana & Yuwono (2014), states that the lower activity energy value, the faster a reaction will run, which means the faster it will contribute to product damage.

Table 1. Calculations of the D, Z, and activity energy of color index at ordo 0 and ordo 1

Ordo	k (minute-1)	ln k	T (°K)	1/T	D (minute)	Log D	Z (°C)	Ea (J/mol)
	0,626	0,4684	353	0,00283	3,6789	0,566		
Ordo 0	0,434	0,8347	363	0,00275	5,3065	0,725	1,972	9,7108
	0,0605	2,8051	373	0,00268	38,0661	1,581		
	0,0098	4,6254	353	0,00283	235	2,371		
Ordo 1	0,007	-4,9618	363	0,00275	329	2,517	2,105	47,5394
	0,0011	6,8124	373	0,00268	2093,6364	3,321		

Table 2. Calculations of the D, Z, and activity energy of pH at ordo 0 and ordo 1

Ordo	k (menit-1)	ln k	T (°K)	1/T	D (menit)	Log D	Z (°C)	Ea (J/mol)
	0,0205	3,8873	353	0,00283	112,3415	2,051		
Ordo 0	0,0097	4,6356	363	0,00275	237,4227	2,376	3,135	38,436
	0,0047	-5,3602	373	0,00268	490	2,690		
	0,0071	4,9477	353	0,00283	324,3662	2,511		
Ordo 1	0,0032	5,7446	363	0,00275	719,6875	2,857	2,967	6,459
	0,0015	6,5023	373	0,00268	1535,3333	3,186		

pH

pH testing with different temperature conditions at temperatures 80°C, 90°C, and 100°C, then the parameter values are plotted against different cooking times, at 20, 30, and 40 minute. Kinetic degradation thermal pH ordo 0 and ordo 1 can be seen in Figure 7.

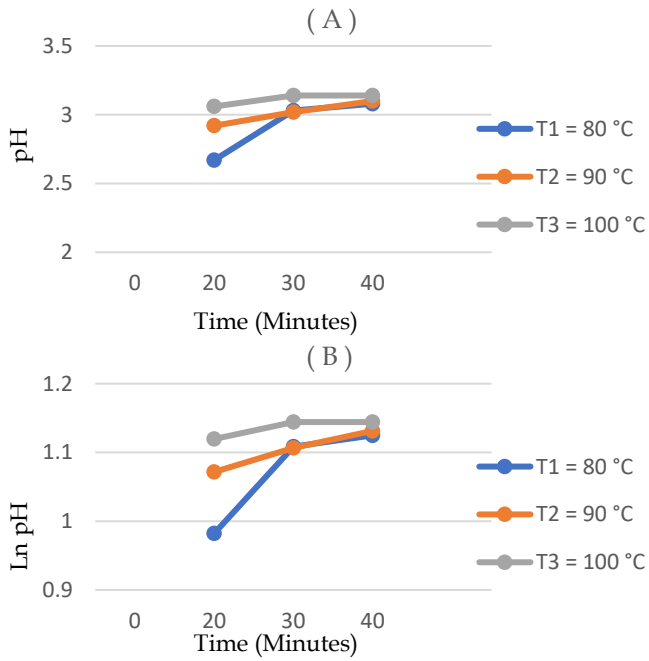

Figure 7. The kinetics of thermal degradation pH (A) Ordo 0 and (B) Ordo 1

Figure 7 shows kinetics of pH thermal degradation using ordo 0, and it can be seen that there is an increase in the pH value during the cooking process in each kepundung syrup product. An increase in the acidity degree (pH) value indicates that kepundung syrup is more durable during storage. The calculation of the D, Z value and activity energy of pH at ordo 0 and ordo 1 can be seen in Table 2. Based on Table 2, the highest D value is in ordo 1, temperature 100 °C at 1535,3333 minute and the lowest is in ordo 0 temperature 80 °C at 112,3415 minute. According to Sukasih (2005), the D value is the time required to reduce pH value by one log cycle at a certain temperature.

The Z value is the temperature change used to reduce pH value to D value by 90% or one log cycle. The Z value in ordo 1 is 2,967 °C, it is smaller than in ordo 0 at 3,135 °C.

The curve for determining the Z value of thermal degradation pH of kepundung syrup can be seen in Figure 8. The curve for determining the activity energy of thermal degradation pH of kepundung syrup during cooking can be seen in Figure 9. Based on Table 2, k value become smaller as the cooking temperature is lower, except at ordo 0 temperature 100 °C. Activity energy (Ea) obtained at ordo 0 is 38,436 J/mol and activity energy at ordo 1 is 6,459 J/mol. This activity energy means that the minimum amount of energy required by molecules in kepundung syrup to reduce the pH value is 6,459 J/mol at ordo 1. Kurniawati (2023) minus sign in ordo 1 regression equation in Figure 9 states that in this rection component degradation occurs.

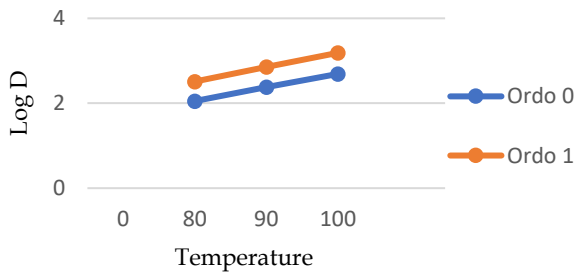

Figure 8. The curve for determining Z value of thermal degradation of pH kepundung syrup

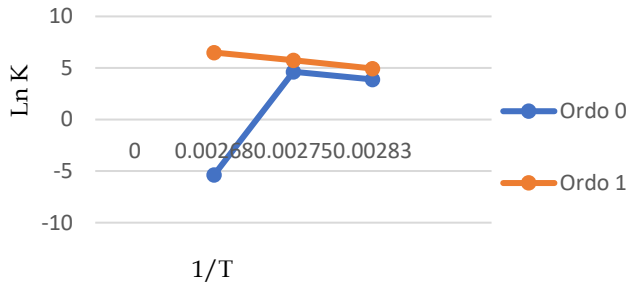

Figure 9. The curve for determining the activity energy of thermal degradation of pH kepundung syrup during cooking

Viscosity

Viscosity testing with different temperature conditions at temperature 80°C, 90°C, and 100°C, then the parameter values are plotted against different cooking times at 20, 30, and 40 minutes. The kinetics of thermal degradation of viscosity at ordo 0 and ordo 1 can be seen in Figure 10.

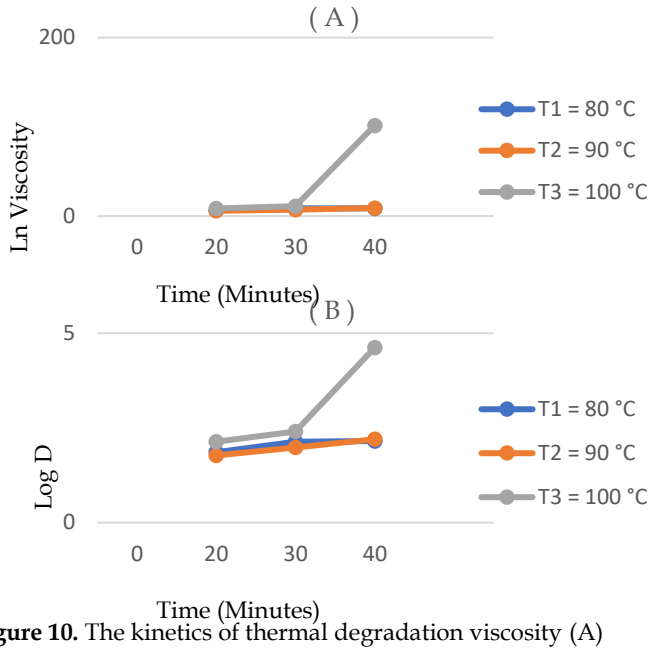

Figure 10. The kinetics of thermal degradation viscosity (A) Ordo 0 and (B) Ordo 1

Table 3. Calculations of the D, Z, and activity energy of viscosity at ordo 0 and ordo 1

Ordo	k (menit-¹)	ln k	T (°K)	1/T	D (menit)	Log D	Z (°C)	Ea (J/mol)
	0,1054	2,2499	353	0,00283	21,8501	1,339		
Ordo 0	0,1493	1,9018	363	0,00275	15,4253	1,188	1,898	3,159
	4,4354	1,4896	373	0,00268	0,5192	0,285		
	0,0148	4,2131	353	0,00283	155,6081	2,192		
Ordo 1	0,0213	3,8490	363	0,00275	108,1221	2,034	2,165	8,838
	0,1242	2,0859	373	0,00268	18,5427	1,268		

Figure 10 shows that R^2 closest to 1 is at ordo 1, so that thermal degradation kinetics of kepundung syrup viscosity uses ordo 1 with R^2 of 0,8063-0,9998. The higher the cooking temperature, the higher viscosity during cooking process of each kepundung syrup product. An increase in viscosity value indicates that the kepundung syrup becomes thicker. Calculation of D, Z value, dan activity energy of viscosity at ordo 0 and ordo 1 can be seen in Tabel 3. The curve for determining Z value of thermal degradation of viscosity kepundung syrup can be seen in Figure 11. The curve for determining the activity energy of thermal degradation of viscosity kepundung syrup during cooking can be seen in Figure 12.

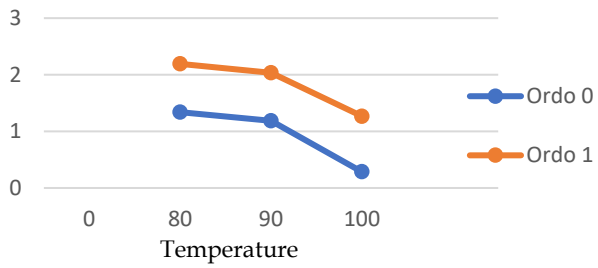

Figure 11. The curve for determining Z value of thermal degradation of viscosity kepundung syrup

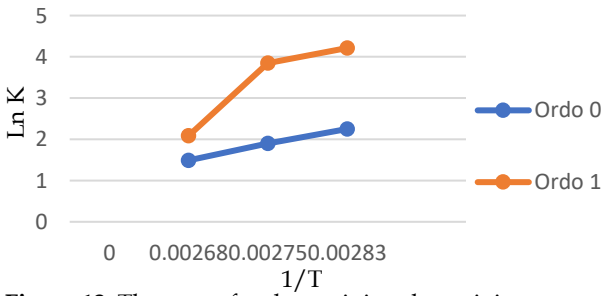

Figure 12. The curve for determining the activity energy of thermal degradation of viscosity kepundung syrup during cooking

Based on Table 3, the largest D value is at temperature 80 °C ordo 1 it is 155,6081 minutes and the smallest at ordo 0 temperature 100 °C it is 0,5192 minutes. The Z value is the temperature required to reach D value. Activity energy (Ea) at ordo 0 obtained is 3,159 J/mol.

Activity energy (Ea) at ordo 1 obtained is 8,838 J/mol. Oceanic, Gunadnya, Widia, Wiranata, & Budisanjaya (2017) stated that, large Ea value indicates a strong interaction energy, so that to start a reaction a large amount of energy is needed. Meanwhile, a low Ea

value indicates that only a small amount of energy needed to start a reaction, a product has undergone a change or extreme decline of quality.

Conclusion

Based on the interaction of temperature and cooking time on pH and viscosity parameters, the best treatment for kepundung syrup is A3B3 (temperature 100°C and cooking time 40 minutes). Based on the determination of the kinetic ordo of thermal degradation, the color index R^2 is closest to 1 at ordo 0 and in the calculation of Ea, ordo 0 is chosen with smaller Ea value. Based on determining ordo of thermal degradation kinetics, pH R^2 closest to 1 at ordo 0 and in the calculation of Ea, ordo 1 is chosen with smaller Ea. Based on determining ordo of thermal degradation viscosity R^2 is closest to 1 at ordo 1 and in the calculation of Ea, ordo 0 is chosen with smaller Ea.

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Author Contributions
The authors listed in this article, have read and agree to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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