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Prediction Shelf Life of Arabica Java Preanger Coffee Beans under Hermetic Packaging Using Arrhenius Method

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Abstract. Java Preanger Arabica coffee is a plantation crop with 2-3 months harvest period annually, therefore the storage system is required to keep the product available throughout the year. Postharvest handling, storage, and packaging particularly are the main factors to be considered so that the coffee beans can be stored for a long time. Hermetic packaging is identified as an effective and safe technology to preserve the quality of grain during storage. Specialty coffee beans cannot be accepted if the total quality value is below 80 according the SCAA protocol, therefore an estimation of the coffee beans shelf life is required. The objective of this research was to analyze and compare the difference between the quality changes of Preanger Arabica Coffee during storage period using hermetic packaging and non-hermetic packaging, and to estimate the shelf life of dried coffee beans based on taste value using ASLT (Accelerated Shelf-Life Testing) method by using Arrhenius approach. Storage simulation was conducted within temperature range of 40°C, 50°C, and 60°C, with 80% relative humidity using both hermetic and non-hermetic packaging. The degradation of quality rate (K value) which was obtained based on the simulation results, was used to predict coffee beans shelf-life by putting it on Arrhenius equation. Coffee packaged with hermetic plastic has a slower rate of quality decline compared to coffee packed with non-hermetic plastic. The predicted shelf-life of coffee beans with hermetic and non-hermetic packaging were 232 days and 45 days (10°C), 113 days and 26 days (15°C), and 57 days and 16 days (20°C), 29 days and 10 days (25°C) respectively.

1. Introduction

Indonesia is the fourth coffee producer in the world after Brazil, Vietnam and Colombia [7] [3]. Arabica coffee has a distinctive taste and is much in demand by other countries, which is a source of increasing foreign exchange. Likewise, coffee from West Java, known as Java Preanger, productivity continues to increase with a market share that also increases from year to year. However, coffee is a plantation crop with a harvest period once a year with a harvest period of 2 -3 months, while market demand occurs throughout the year, so coffee beans must be stored so that they are available at all times.

Therefore, postharvest handling, especially storage methods, is the main factor that needs to be considered so that the quality of coffee is maintained during storage. In addition to temperature and storage time, one of the important factors in storing coffee is the type of packaging [1] [2]. Hermetic plastic packaging is a package made from special materials and techniques to create a tight environment from outside influences [5] [6], especially on water and gas including CO₂, O₂ and N₂ [1]. The basic materials of hermetic packaging consist of plastic High Density Polyethylene (HDPE) which functions as a barrier to oxygen, while Polyvinyl Chloride (PVC) plastic serves to give strength to the packaging [9]. This packaging is suitable for certain products that require manipulation of atmospheric conditions, with the aim of preventing pest attacks, reducing product respiration [6], and maintaining sensory quality, especially the aroma of the packaged material [12].



During storage, coffee beans decline in quality and the length of shelf life is affected, among others, by temperature, relative humidity and the type of packaging. According to the Specialty Coffee Association of America (SCAA), specialty coffee beans cannot be accepted if the taste value is less than 80, so a shelf life estimation is needed to determine the quality changes of coffee during the storage period. One method of estimating shelf life is Accelerated Shelf-Life Testing (ASLT) with the Arrhenius approach [4]. Quality reduction analysis with this method requires several observations, namely parameters measured quantitatively that reflect quality changes that occur during storage [13]. The objectives of this study are 1) to analyze the quality degradation of Preanger Arabica coffee beans during the storage period with hermetic packaging and compare them with non-hermetic plastic packaging, and 2) to estimate the shelf life of Preanger Arabica coffee beans based on flavor value parameters using the ASLT method with Arrhenius approach.

2. Methodology

2.1 Tools and Materials

The tools used in testing the shelf life of this coffee bean product are digital scales, Grainpro SGB PREMIUM-15RZ hermetic plastic packaging with high strength polyethylene material with barrier, non-hermetic plastic packaging in the form of low density polyethylene (LDPE) plastic, coffee roasting machines W600 type direct flame drum, and KCL-2000 Eyela incubator. The main material used in this study was the Preanger Arabica coffee (greenbean) from the Frinsa plantation in the village of Weninggalih, West Bandung regency.

2.2 Research Method

The study was conducted in 4 stages, namely sample preparation, determination of the taste value of coffee beans, simulations accelerating the decline in the quality of coffee beans during storage, and estimation of shelf life with the Arrhenius approach.

2.2.1 Sample Preparation

500 grams of dried coffee beans were packed into 12 hermetic plastic packages and 12 non-hermetic plastic packages, so the total samples were 24 packs of coffee beans @ 500 grams. The samples were put into an incubator that has been set with RH 80% and three temperature levels (40°C, 50°C, and 60°C) as a storage simulation.

2.2.2 Determination of the Taste Value of Coffee Beans Using the Cupping Method

Determination of the taste value of coffee was done by cupping method which refers to the SCAA cupping protocol [7], which consists of 3 main parts, namely sample preparation, sensory evaluation, and assessment. The sample preparation process consists of roasting, grinding and brewing. The next step was sensory evaluation carried out by 3 panelists or Q-graders. Coffee that had been brewed for 3-5 minutes was stirred using a cupping spoon, an assessment was based on the attributes of flavor, aroma, flavor, aftertaste, acidity, body, uniformity, balance, clean cup, sweetness and overall. Based on these 10 attributes, coffee was classified based on the final total score according to the SCAA as in Table 1, where coffee is not suitable for consumption if the final score reaches 30 or less.

Table 1. Coffee qualifications based on total taste values

<i>Total Score</i>	<i>Quality</i>	<i>Classification</i>
90-100	<i>Outstanding</i>	<i>Specialty</i>
85-89.99	<i>Excellent</i>	
80-84.99	<i>Very Good</i>	
<80.0	<i>Below Specialty Quality</i>	<i>Not Specialty</i>

2.2.3 Prediction of Shelf-life of Coffee Beans during Storage

Estimation of shelf life was carried out using the accelerated shelf life testing (ASLT) method with the Arrhenius approach, which was able to predict the actual shelf life by simulating quality degradation data obtained during observation. Samples were stored in extreme conditions, namely at high temperatures of 40, 50 and 60°C, and measured parameters that reflect changes in quality during storage [8], [10], [11], [13]. The Arrhenius equation shows the dependence of the deterioration reaction rate on temperature which is formulated as follows:

$$K = K_o \cdot e^{-E_a/RT} \quad (1)$$

$$\ln K = \ln K_o - (E_a/RT) \quad (2)$$

$$\ln K = \ln K_o - \{(E_a/R) \cdot (1/T)\} \quad (3)$$

where, K = reaction rate constant at temperature T , K_o = pre-exponential constant, E_a = Activation energy (cal/mol), T = Absolute temperature ($^{\circ}\text{K}$), R = Gas constant (1,986 cal/mol $^{\circ}\text{K}$). The activation energy (E_a) in this equation shows the magnitude of the effect of storage temperature on the reaction that occurs in food. The activation energy value is obtained from the slope of the straight line graph $\ln K$ to $(1/T)$. Large activation energy indicates that a slight increase in storage temperature will make the $\ln K$ value increase significantly.

3. Results and Discussions

3.1 Determination of the Initial Taste Value of Coffee Beans

The coffee sample in the initial condition received a total final score of 85.75 so that it was included in the specialty category (above 80), as can be seen in Figure 1.

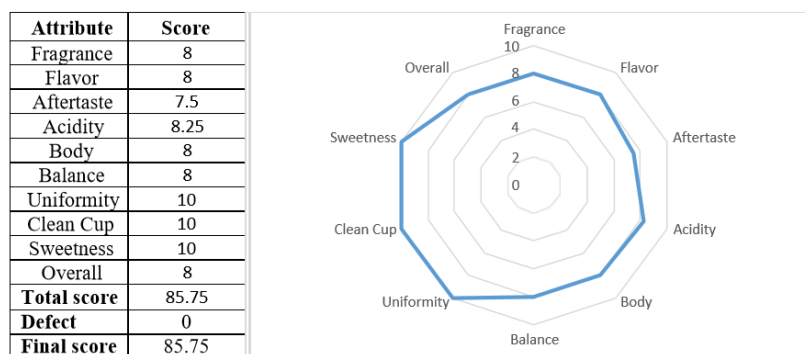


Figure 1. Test results for the taste value of coffee beans without treatment

The value of 10 on uniformity attributes shows that this coffee flavor has good consistency, while the value of 10 on the clean cup attribute and the value of 0 defect shows that the coffee processing is done cleanly so that no dirty taste or aroma is found in coffee.

3.2 Simulation of the Acceleration of Decreasing Quality and Analysis of Declining Value of Coffee Flavors during Storage

The simulation results of storing packaged coffee at various temperatures with decreasing quality are presented in Table 2.

Table 2. Data of decreasing the value of coffee taste during storage

Days	Total Score of Cupping Test					
	40°C		50°C		60°C	
	Hermetic	Non-Hermetic	Hermetic	Non-Hermetic	Hermetic	Non-Hermetic
0	85.75	85.75	85.75	85.75	85.75	85.75
2	85.5	85.5	85.25	84.5	56	55.5
4	85.25	85.25	84	83.5	41.75	39.5
6	85	76.75	83	71	36.25	34.75
8	78.5	73.25	70.5	69.5	25.25	25

After obtaining data on quality degradation for each storage temperature and packaging materials (Table 2), then the graph of the linear regression equation was calculated as follows:

Hermetic 40°C :	$Y = -1.5x + 88.5$	$R^2 = 0.5902$
Hermetic 50°C :	$Y = -3.275x + 91.525$	$R^2 = 0.6644$
Hermetic 60°C :	$Y = -14.075x + 91.225$	$R^2 = 0.9093$
Non-Hermetic 40°C :	$Y = -3.375x + 91.425$	$R^2 = 0.8221$
Non-Hermetic 50°C :	$Y = -4.6x + 92.65$	$R^2 = 0.8457$
Non-Hermetic 60°C :	$Y = -14.225x + 90.775$	$R^2 = 0.8961$

The value of K for each temperature and type of packaging wa obtained from the value of the slope of each graph. Then the $\ln K$ value was plotted into a semi logarithmic graph (Arrhenius plot), where $\ln K$ as ordinate and $1/T$ (temperature in Kelvin) as abscissa to get the value of $-E/R$ for each type of package. The Arrhenius plot for hermetic and non-hermetic packaging can be seen in Figure 2.

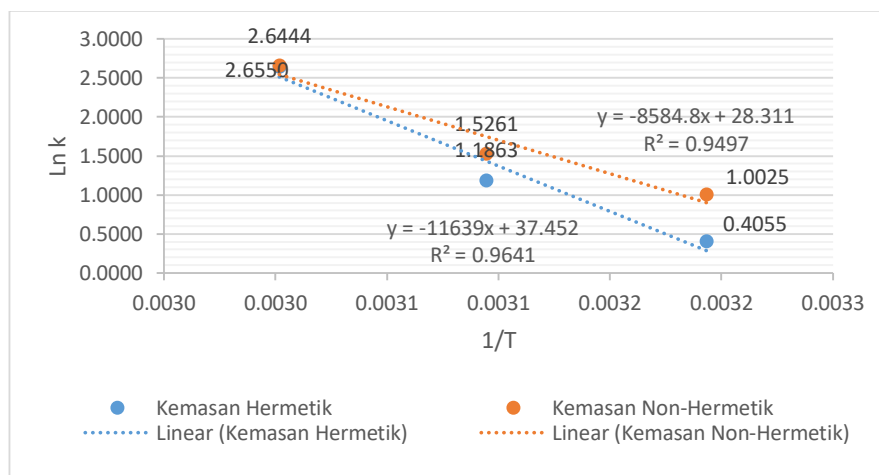


Figure 2. Relationship between the value of $\ln K$ with $1/T$ coffee beans using hermetic and non-hermetic plastic packaging

Based on Figure 2, the relationship of the straight line equation between the values of $\ln K$ and the value of $1/T$ for each packaging was obtained, as follows:

Hermetic packaging	: $Y = -11639x + 37.452$ $R^2 = 0.9641$
Non-hermetik packaging	: $Y = -8584.8x + 28.311$ $R^2 = 0.9497$

The slope value of the equation is the value of $-E/R$ for each equation. The value of R is the gas constant ($1,986 \text{ cal/mol}^\circ\text{K}$) and the activation energy value is the value of E in the equation, so that the activation energy for each packaging can be obtained as shown in Table 3.

Table 3. The value of $-E/R$ for each type of packaging

	$-E/R$	$R \text{ (cal/mol}^\circ\text{K)}$	$E \text{ (cal/mol}^\circ\text{K)}$
Hermetic packaging	-11639	1.986	23115.054
Non-hermetic packaging	-8584.8	1.986	17049.4128

The intercept value in the semi logarithmic graph is the value of $\ln K_0$ in the Arrhenius equation, so the results of $\ln K_0$ and K_0 were obtained as shown in Table 4.

Table 4. $\ln K_0$ and K_0 values for each type of packaging

	$\ln K_0$	K_0
Hermetic packaging	37.452	1.842
Non-hermetic packaging	28.311	1.974×10^{12}

Arrhenius equation can be arranged based on the value of $-E/R$ and K_0 that has been obtained. After the Arrhenius equation for each type of packaging is obtained, then the rate of declining of coffee bean taste can be calculated then called K value based on storage temperature and type of packaging as shown in Table 5. K values obtained from calculations with Equation 6, and estimation of shelf life of coffee beans obtained by entering the rate of deterioration (K) in Equation 7, i.e. :

$$K = K_0 e^{-E/RT} \quad (6)$$

$$t = \frac{A_0 - A}{K_0 \cdot e^{-E/RT}} \quad (7)$$

Table 5. K values and estimation of shelf life for each storage temperature and type of packaging

Type of Packaging	Storage Temperature	K	$t \text{ (days)}$
Hermetic	40 °C or 313.15 K	1.329	4.5
	50 °C or 323.15 K	4.198	1.4
	60 °C or 333.15 K	12.376	0.5
Non Hermetic	40 °C or 313.15 K	2.451	2.5
	50 °C or 323.15 K	5.726	1
	60 °C or 333.15 K	12.711	0.5

The initial coffee taste value of 85.75 was then denoted by the letter A_0 in Equation 7. Coffee is considered not included in the specialty category if the taste value is below 80 or has reached the value of 79.75, and this value is hereafter referred to as critical taste value (A). Estimation results of coffee shelf life at storage temperatures of 40°C, 50°C, and 60°C were estimated at 4.5 days, 1.4 days and 0.5 days for hermetic packaging, and 2.5 days, 1 day and 0.5 days for non-hermetic packaging, respectively. According to the reaction rate theory, increasing temperature will cause an increase in reaction rate because rising temperatures will result in an increase in kinetic energy in the particles. This condition will accelerate the movement of molecules and increase the number of collisions that occur between particles, so that the faster the reaction occurs. This also occurs in coffee beans in the packaging, where reactions can occur from within coffee, such as fat oxidation; coffee reaction with packaging where migration of packaging substances is absorbed in coffee; and also the reaction of coffee with substances outside the environment that can penetrate the packaging such as absorption of moisture content, and the growth of bacteria or fungi.

According to [1] in his book entitled "Handbook of Coffee Post-Harvest Technology", raw or green coffee beans should be stored at temperatures between 10-17 °C, or store at room temperature (20-30°C) with proper packaging. Therefore a shelf life estimation was done at temperatures of 10 to 30°C, the results are presented in Table 6 and Figure 8.

Table 6. K values and estimation of shelf life for each storage temperature and type of packaging

Type of packaging	Storage Temperature	$^{\circ}\text{K}$	t (day)
Hermetic	10 °C or 283.15 K	0.026	232
	15 °C or 288.15 K	0.053	113
	20 °C or 293.15 K	0.105	57
	25 °C or 298.15 K	0.205	29
	30 °C or 303.15 K	0.390	15
Non Hermetic	10 °C or 283.15 K	0.134	45
	15 °C or 288.15 K	0.227	26
	20 °C or 293.15 K	0.378	16
	25 °C or 298.15 K	0.617	10
	30 °C or 303.15 K	0.992	6

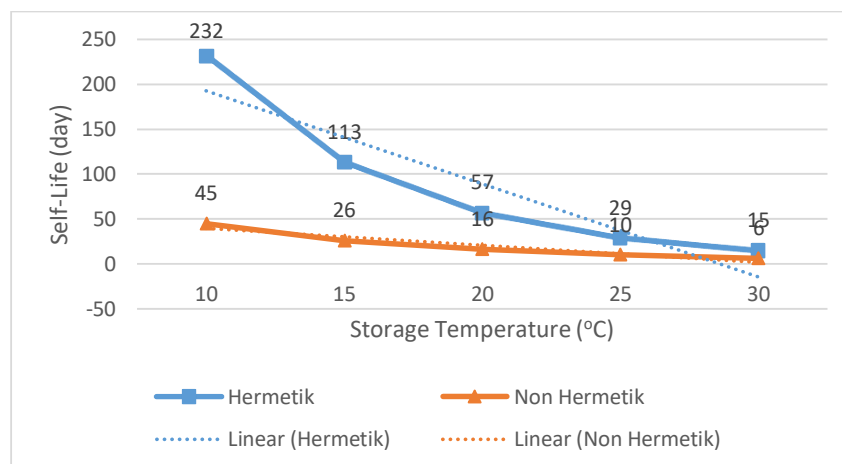


Figure 3. Relationship between storage temperature and estimated shelf life

As can be seen in Figure 8 that hermetic plastic packaging has a better ability to maintain coffee quality than non-hermetic plastic packaging. At storage temperatures of 10°C to 30°C coffee beans can last up to 15 to 232 days for hermetic packaging, and 6 to 45 days for non-hermetic packaging. Specialty coffee shelf life is strongly influenced by the rate of decline in the final score of taste value during storage, the lower the rate of declining taste, the longer the shelf life.

4. Conclusions and Suggestions

Coffee packaged with hermetic plastic has a slower rate of decline compared to coffee packed with non-hermetic plastic. The shelf life estimation using the ASLT method with the Arrhenius approach shows coffee shelf life of 232 days with hermetic packaging at 10°C, 113 days at 15°C, 57 days at 20°C, 29 days at 25°C, and 15 days at 30°C. With non-hermetic packaging the shelf life is shorter, which is 45 days at 10°C, 26 days at 15°C, 16 days at 20°C, 10 days at 25°C, and 6 days at 30°C.

Suggestions for research on shelf life estimation in agricultural products using the ASLT method and Arrhenius approach, critical parameters used must be able to represent quality in general, including organoleptic testing.

5. References

- [1] Borem FM, Riberio FC, Figueiredo LP, Giomo GS, Fortunato VA, Isquerdo EP. 2013. Evaluation of the sensory and color quality of coffee beans stored in hermetic packaging. *J of stored product research* 52:1 – 6.
- [2] Bhumiratana, N., K. Adhikari, and E. Chambers. 2011. Evaluation of sensory aroma attributes from coffee beans to brewed coffee. *LWT Food Science and Technology* 44: 2185-2192.
- [3] Direktorat Jendral Perkebunan. 2015. Statistik Perkebunan Indonesia (Kopi) 2014-2016. Jakarta (ID).
- [4] Ellis, MJ. 1994. The methodology of shelf life determination in Shelf Life Evaluation of Foods. Ed. CMD Man and AA Jones. Blackie Academic and Professional. Glasgow.
- [5] Emblem A. 2012. Plastics properties for packaging materials. Woodhead Publishing UK.
- [6] Guenha R, Salvador BDV, Rickman J, Goulao LF, Muocha IM, Carvalho MO. 2014. Hermetic storage with plastic sealing to reduce insect infestation and secure paddy seed quality: A powerful strategy for rice farmers in Hine, DJ. 1997. Modern Packaging, Packaging, and Distribution System for Food. Blackie. London.
- [7] ICO (2014). Statistik Perdagangan. www.ico.org, London: International Coffee Organization.
- [8] Labuza, TP 1982. Open shelf-life Dating of Foods. Food Science and Nutrition, Press Inc., Westport, Connecticut.
- [9] Marsh K, Bugusu B. 2007. Food Packaging Roles, Materials, and Environmental Issues. *J Food Sci.* 72:39-55.
- [10] Morten C. Meilgaard, B. Thomas Carr, Gail Vance Civile. 2006. Sensory Evaluation Technique. Detroit. United States. CRC Press.
- [11] Nurcahyanti, A. 2005. Pengemasan dan Pendugaan Umur Simpan Keripik Talas dalam Kemasan Plastik PP, OPP/VMCPP, and PET/DL/VMPET/SPE dengan Metode Akselerasi [skripsi]. Bogor (ID): Institut Pertanian Bogor.
- [12] Ribeiro FC, Borem FM, Giomo GS, Lima RRD, Malta MR, Figueiredo LP. 2011. Storage of green coffee in hermetic packaging injected with CO₂. *J of stored product research* 47:341 – 348.
- [13] Syarif R and H. Halid. 1993. Teknologi Penyimpanan Pangan. Pusat Studi Antar Universitas. IPB. Bogor.