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Evaluation of Shelf Life of Arabica Mixed Coffee Drinks Using Accelerated Shelf Life Testing Method

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Abstract

Coffee is a popular drink that is often consumed by Indonesian people. Currently, many manufacturers develop a variety of diverse coffee beverage products to provide flavor as well as good functional properties. Arabica coffee drinks in this study were made from three parts of coffee, i.e. cascara, which is the skin of coffee fruit; green coffee beans; and roasted coffee beans. This beverage products were then packaged and stored in a ready to drink glass bottle. This study aimed to determine the shelf life of mixed Arabica coffee beverage products, using the ASLT method. Samples were stored under different temperature conditions: 4^{O}C, 27^{O}C and 37^{O}C. The test consisted of measuring pH, total dissolved solids (ppm), total sugar (^{O}Brix), total color difference (△E) and total plate count (log CFU/mL). The results showed that during storage of mixed Arabica coffee drinks, a pH value decreased from 5.56 to 5.42-3.67, indicating that the product was getting more acidic. The number of microbes increased, from 1.92 log CFU/mL to 4.64-6.37 log CFU/ mL. Each parameter had a different activation energy value. The higher the storage temperature was proven to the smaller the activation energy. On the measurement of total microbes, the activation energy of each treatment temperature of 4^{O}C, 27^{O}C and 37^{O}C were 0.1731, 0.1476 and 0.1382, respectively. This Arabica coffee drinks had a shelf life of 4 days if stored at 4^{O}C.

Keywords: Accelerated shelf life testing (ASLT), Arabica coffee bean, cascara, green bean, shelf life

INTRODUCTION

Indonesia is the fourth coffee producing country after Brazil, Vietnam, and Colombia (Kemenperin, 2017). According to data from the BPS (2018), coffee production in Indonesia is increasing every year. Coffee production in 2015 was around 602.37 thousand tons, in 2016 it reached 632 thousand tons and in 2017 it reached 636.7 thousand tons. The increasing amount of coffee production in Indonesia each year, it makes more coffee processed products by the coffee industry (Kurniawan & Rosyid, 2017).

According to Abduh (2018), the types of coffee that are famous in Indonesia are Robusta (*Coffea canephora*) and Arabica (*Coffea arabica*). However, Arabica coffee is often used as a raw material in the manufacture of coffee drinks because it has a superior taste and complex aroma compared

to Robusta coffee (Rakesh *et al*., 2010). Coffee can be enjoyed by brewing with hot water (hot brew) and cold water (cold brew). According to the Kemenperin (2017), cold brew has become the latest trend of consuming coffee drinks that are previously served always in a hot state. Cold brew coffee is starting to become a trend with several advantages such as having less acid content and having higher caffeine levels (Fuller & Rao, 2017).

In general, coffee commonly consumed as a drink is roasted coffee beans (Kipkorir *et al*., 2015). However, it is known that green coffee beans and cascara can also be used as raw material for drinks. The samples of coffee cherry pulp obtained from coffee producers from different parts of the world, differing in variety and type of processing showed significantly different contents of phenolic compounds and caffeine. Among the assessed samples, Bourbon variety originating from Congo had highest total polyphenol content and antioxidant capacity and high caffeine content. Compared to coffee and silverskin tea, cascara has high levels of caffeine and antioxidant activity (Heeger *et al*., 2016). Until now there have been many studies conducted on mixed Arabica and Robusta coffee products, but there has been no research on mixed coffee products: cascara, green coffee and roasted coffee. This is the development of coffee beverage products, which also can increase the added value of cascara, green coffee and roasted coffee. Coffee pulp is a natural antioxidant and tannin provider, proven to bring beneficial health aspects to a person. According to the panelist reviewed, washed process cascara was preferred to natural process cascara. Washed process cascara was always 1 or 2 points above in all attributes evaluated (color, sweetness, taste and general acceptance) (Umanzor, 2016).

Research related to shelf life is very important, especially for perishable food products. An estimated shelf life method is the ASLT method. This method is to determine the shelf life with the accelerated method by storing the product in environmental conditions that can accelerate the reaction of product quality degradation. In this method the storage conditions are set outside normal conditions so that the product can be damaged more quickly and the shelf life of the product can be determined (Arif, 2016). Based on the study of Sudibyo *et al.* (2010), the critical parameter that determines the shelf life of instant coffee products is the water content. The critical point value of water content is 17.98%, the shelf life of the instant coffee product formulation that was studied at 30^{O}C, 45^{O}C and 50^{O}C were 664 days, 437 days and 384 days, respectively.

The shelf life of food products is also very important information for consumers due to it is related to food product safety and provides quality assurance when the product reaches consumers. Information related to shelf life is one of the conditions that must be displayed on the packaging label to processed products to be traded. In this study, the drink formulation used between cascara; green beans; roasted beans is 1:1:1. This is based on preliminary research conducted on formulation that can be accepted by consumers. In additions, comparison intends that there is no dominating taste among the main ingredients of coffee due to each of the product has different characteristics, such as cascara which dominates the sour taste, green coffee dominates the beany taste while roasted coffee dominates the bitter taste. This study aimed to determine the shelf life of cascara extract, green coffee and roasted coffee mixed drinks with ASLT method.

MATERIALS AND METHODS

The materials used in this study were dry cascara, green coffee beans, roasted coffee beans, Arabica type Java Karlos Gunung Arjuna Malang, East Java, obtained from Nomar Kopi Roastery, and the addition of brown sugar, maltodextrin and full cream milk. Roasted coffee beans are ground using a grinder. Then the cold extraction process is carried out on the roasted coffee beans and cascara for 12 hours using a french press, while the green coffee beans are extracted hot by boiling. The comparison made for extraction is 1:15. Then the extraction results are mixed homogeneously, which will produce a mixed drink from cascara extract, green coffee and roasted coffee added with brown sugar, maltodextrin and full cream milk to increase the flavor of the beverage product.

Accelerated Shelf Life Testing (ASLT) was carried out on samples with glass bottle packaging at 37^{O}C, 27^{O}C and 4^{O}C for 12 days. The parameters tested were measurements of color (L*, a*, b*), pH, total dissolved solid (TDS), total sugar (^{o}Brix) and total plate count (TPC). Observations were made on days 0, 3, 6, 9, 12, and 15.

Analysis data from observations will be entered into a graph of the relationship between storage time (days) with the average change in a quality decrease for each parameter. Then the linear regression equation (y = bx + a) is obtained, which is obtained by three equations for three different storage temperature conditions. Where y is the change in product quality, b is the rate of change in the quality of the product obtained from the slope (also known as k), or is called k, x is the storage time (days) and a is the initial product quality value.

Then the reaction order is determined by using a zero-order graph which is the relationship between the value of k with the storage time and order one which is the relationship between ln k with the storage time. The zero-order decrease graph is a constant quality loss and can be illustrated by the $A_t - A_o = -kt$ equation while the first-order graph is done with a plot of ln k value with long storage. The correlation of decreasing quality parameters for first-order is illustrated by the

$\ln A_t - \ln A_o = -kt$ equation where :

A_t = Value of the quality parameter at time t
A_o = Initial value of quality parameter A
k = Rate of change in quality
t = Storage time

Determination of the reaction order is based on a linear regression equation by looking at the value of R^2, where the largest R^2 value will be chosen as the reaction order. The Arrhenius approach is used by graphing the correlation of the rate of decline in product quality to the storage temperature connecting the value of ln to 1/T. Then make the linear regression equation with the equation $\ln k = \ln k_0 - (E/RT)$ approach, where $\ln k_0$ = intercept, E/R = slope, E = activation energy and R = ideal gas constant = 1,986 cal/mol^{o}K (Asiah *et al*., 2018).

After obtaining the value of k_0 which is a pre-exponential factor and the value of the reaction activation energy (Ea) changes in product characteristics, the Arrhenius equation will be obtained which is the equation of reaction rate changes in the quality characteristics of drinks with the equation $k = k_0.e^{-E/RT}$ where T is storage temperature. Arrhenius constant values at each storage temperature can be calculated.

The parameter that has the lowest activation energy value is a key parameter. Shelf life is calculated using the reaction equation based on the reaction order. To determine the shelf life of beverage products is to enter the temperature value in the equation ln k

= ln k_0 - (E/RT). The k value obtained is entered into the reaction order equation to get the shelf life of coffee drinks (Swadana & Yuwono, 2014).

RESULTS AND DISCUSSION

Quality Characteristics

Preliminary quality characteristics need to be tested to determine the initial state of the sample before storage so that estimation of shelf life can be done through the identification of defects that occur during storage on beverage products. The quality characteristics of the initial coffee drinks can be seen in Table 1.

Determination of the final quality (N_t) of beverage products, carried out to get the value of the final quality standard of products that are carried out sensory. The test used 20 untrained panelists. This test was carried out because there were no standards for mixed coffee beverage products. The sensory test used is a triangle test. The results obtained from the percentage of rejection of 50%, that the determination of the final quality of the product is determined from the physicochemical value and TPC (total plate count) at the temperature of 4 days 6 (Table 2).

Quality Changes

Determination of shelf life of mixed coffee beverage products is carried out the physicochemical testing including measurement of pH, TDS (total dissolved solid), total sugar, total color difference, and TPC. Following are the changes in the physicochemical quality and total microbial of Arabica coffee mixed beverage products during storage.

Table 1. Initial quality characteristics of coffee beverage products

Quality parameters	Initial quality (N_0)	Final quality (N_t)
Total sugar (TS) (°Brix)	9	8.97
pH	5.56	5.44
Color:		
Brightness level (L*)	34.29	36.22
Red intensity (a*)	4.82	4.30
Yellow intensity (b*)	11.82	10.59
Total dissolved solid (TDS) (ppm)	1223	1410
Total plate count (TPC) (cfu/mL)	82.5	2575

Table 2. Total color difference (△E) during storage

Temperature (°C)	Days to...	Color parameters			
		ΔL*	Δa*	Δb*	ΔE*
4	0	0.00	0.00	0.00	0.00
	3	1.41	-0.45	-0.95	1.76
	6	1.93	-0.52	-1.23	2.35
	9	2.01	-0.58	-2.65	3.38
	12	3.21	-0.55	-1.68	3.67
27	0	0.00	0.00	0.00	0.00
	3	-2.02	0.08	-1.67	2.62
	6	-3.69	-0.05	-2.83	4.65
	9	-3.96	-0.42	-3.02	4.99
	12	-6.22	-0.79	-4.27	7.58
37	0	0.00	0.00	0.00	0.00
	3	-2.12	-1.63	-6.24	6.78
	6	-4.91	-1.57	-4.57	6.88
	9	-7.34	-0.65	-8.45	11.21
	12	-9.77	-0.97	-5.47	11.24

pH

The pH value is the degree of acidity which shows the concentration of hydrogen ions which states the level of acid or base in a solution (Sudewa & Hadiatna, 2017). During product storage, there is a decrease in the pH value (Figure 1). The lower pH indicates a high level of product acidity. The decrease in pH is due to the formation of acid in coffee beverage products produced by microbial activity, so the longer the storage is proving the more acidic the pH of the beverage product. This is similar to the statement of Yun *et al.* (2007) that the gradual decrease in pH is caused by chemical reactions and the growth of microorganisms. Microorganisms that grow on products can produce organic acids and breakdown hydrolytic lipids that can produce fatty acids. That is what causes a decrease in pH.

The change in pH is thought to be due to the activity of microorganisms that can break down proteins, carbohydrates, fats, and other organic substances into organic acids so that it can cause a decrease in pH value. Microbes that can produce acids, including lactic acid bacteria or acetic acid bacteria (Rahayu & Nurwitri, 2012).

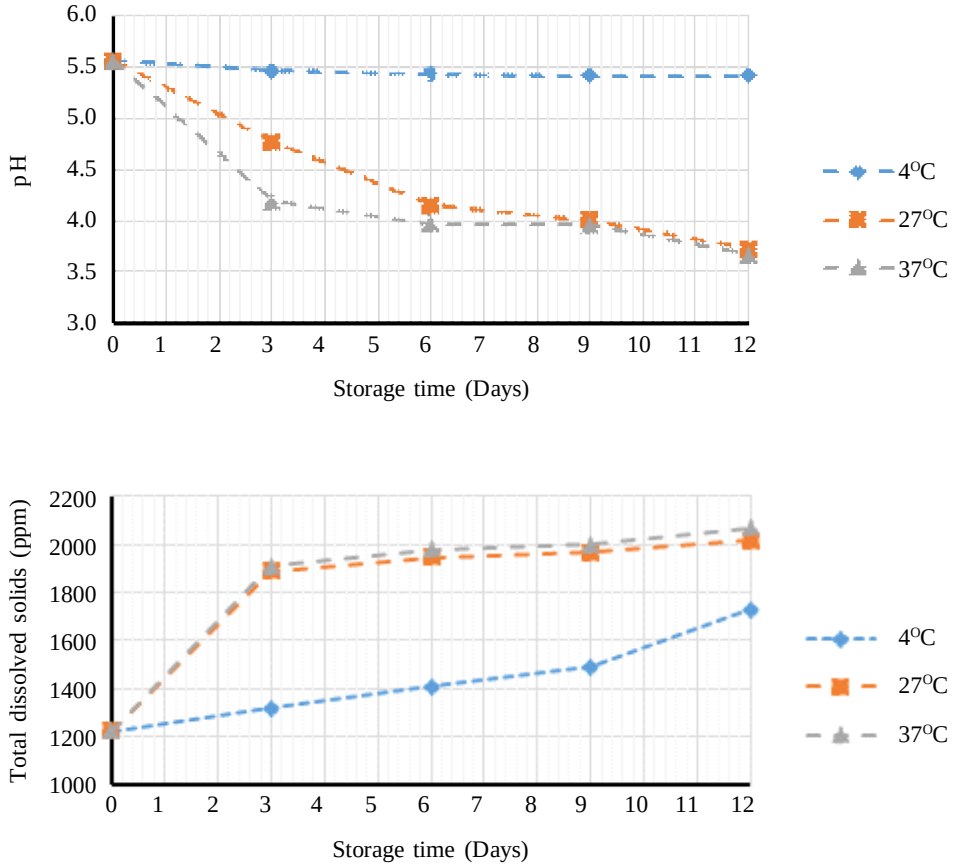

Figure 1. Changes in pH and TDS

TDS

During storage of coffee beverage products, an increase in the value of TDS. This increase in TDS is due to the formation of lumps in coffee beverage products (Figure 2). Beverage products are included in the colloidal type dispersion system. A colloid is a mixture of several substances that are located between the nature of the solution and suspension. Generally, colloids have particle sizes between 1 nm to 100 nm (Adi, 2013). Colloids become unstable when coagulation occurs. This coagulation can be interpreted as one of the protein damage that occurs due to heat, resulting in clotting (Makfoeld, 2008).

During storage at 27^{O}C and 37^{O}C, the samples formed deposits and lumps. This is due to the sample has rich nutrients. The high nutritional value of milk can cause milk to be easily damaged at high storage temperatures. The fat and protein contained therein are denatured due to heat. Rahayu & Nurwitri (2012) explained that almost all components of milk are nutrients that are loved by microbes to grow. Microbiological damage to milk can be caused by acid production in several species of bacteria and yeast.

Parameter of Total Sugar (^{o}Brix)

During storage of beverage products, there is a decrease in the value of total sugar. Carbohydrates (in this case sucrose) as the main substrate that can be broken down by microbes in the fermentation process into simpler sugar units, resulting in a decrease in the total value of sugar solids (^{o}Brix). (Figure 2).

The decrease in total sugar can be caused by the conversion of polysaccharides that are soluble in reducing sugars, as well as the hydrolysis of sugars by acids where there will be the degradation of disaccharides into monosaccharides, as well as hydrolysis of sucrose. This reducing sugar is formed by microbial fermentation (Yadav *et al.*, 2013).

Total Color Difference Parameter (∆E)

Color measurements are carried out using a chromameter that will produce Hunter values in the form of L*, a* and b*. According to Andarwulan *et al.* (2011), Hunter color notation system is characterized by three color parameters are chromatic color (hue) written with the notation L*, a* and b*. The notation L* states the brightness parameter (lightness) with the value 0 means black and 100 means white. The notation a* represents the chromatic color mixture of red-green with positive values a* from 0 to +100 for red and negative values a from 0 to -80 for green. Whereas the b* notation states the chromatic color mixture of blue-yellow with positive values of b* from 0 to +70 for yellow and negative b* from 0 to -70 for blue. As a result of a decrease in the pH value and an increase in the TDS value in the previous parameters, it will affect the change in the total color value during storage. The higher the storage temperature, the change in the total color value is also higher (Figure 2).

The value of ∆L* at 4^{O}C temperature increases with a positive value during storage, which indicates that the color of the beverage product gets brighter with storage time, whereas at temperatures of 27^{O}C and 37^{O}C decreases the brightness during storage with a negative value, which indicates that the product is getting turbid or more colored dark. The value of ∆a* at 4^{O}C, 27^{O}C and 37^{O}C decreases during storage with a negative value, which indicates that the coffee drink product is greenish, while the value of b* at 4^{O}C, 27^{O}C and 37^{O}C also decreases during storage with a negative value, indicating that bluish-colored coffee beverage products (Table 3).

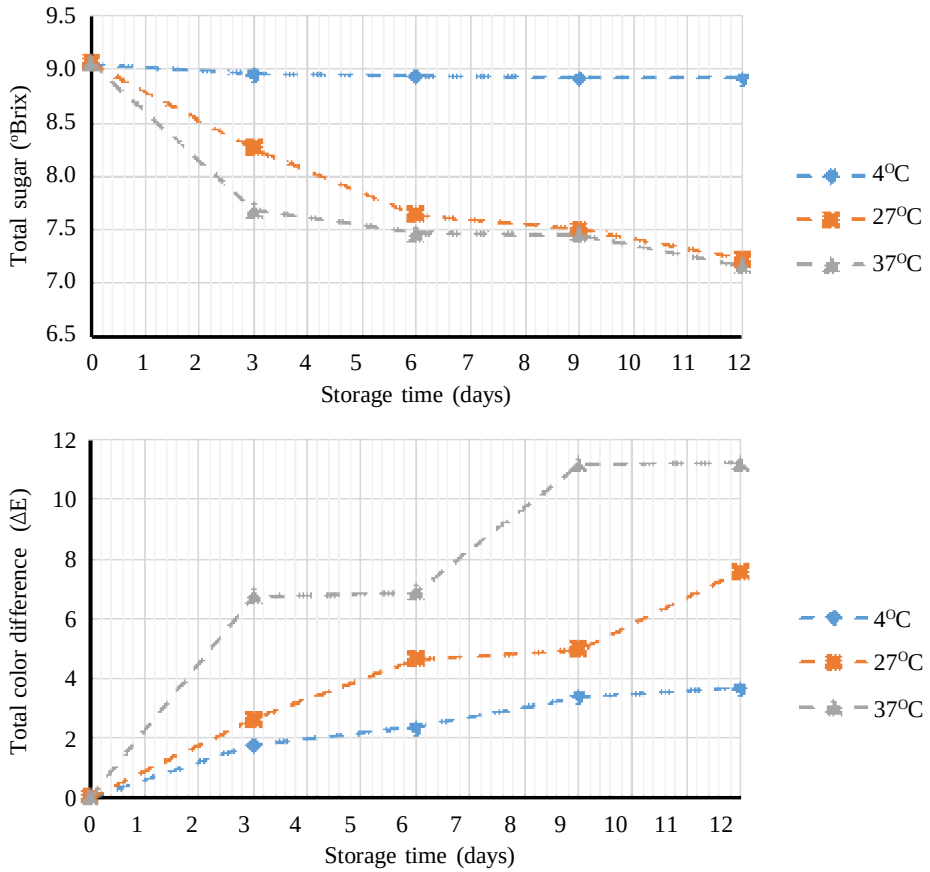

Figure 2. Change in °Brix value and total color difference during storage

This color change indicates a change or decrease in product quality, according to the statement of Culver (2008), which states that color is one of the characteristics that largely determines the quality of a food product.

Research conducted by Guo *et al*. (2011) and Xu *et al*. (2011) grouped the value of ΔE* into five groups that is not visible when ΔE* 0 - 0.5, at first glance seen when ΔE* 0.5 - 1.0; slightly visible when ΔE* 1.5 - 3.0; looks good when ΔE* 3.0 - 6.0; and clearly seen when ΔE* 6.0 - 12.0.

Total Plate Count

According to Rahayu & Nurwitri (2012), growth and activity of food-destroying microorganisms can have an impact on food quality and quantity reduction. A decrease in the pH parameters and total sugar (°Brix), as well as an increase in the TDS parameters during storage, indicates that there is micro-organism activity in beverage products. Micro-organism testing is done by testing the TPC. During storage, there is an increase in the total number of microbes in beverage products (Figure 3). The higher the storage temperature, the more microbes will be in the beverage product. Microorganism test using this TPC method can find out the total number of microorganism in the sample by growing microorganism cells that are still alive. So, that is known during storage, there is an increase in the total number of microbes in the Arabica mixed coffee beverage product. Storage at high temperature causes an increase in the number of microbes that are higher than the lower temperature.

Table 3. Determination of the order of reaction

Parameter	Temperature (°C)	R^2		Order
		Order 0	Order 1	
pH	4	0.7529	0.7551	1
	27	0.9145	0.939	
	37	0.7254	0.7616	
TDS (ppm)	4	0.9432	0.9641	0
	27	0.6334	0.6075	
	37	0.6584	0.627	
TSS (°Brix)	4	0.9423	0.9421	1
	27	0.5967	0.602	
	37	0.8076	0.8264	
Total Color Difference (ΔE)	4	0.933	0.9509	0
	27	0.9568	0.9263	
	37	0.8568	0.8136	
TPC (cfu/mL)	4	0.3655	0.8591	1
	27	0.2443	0.8318	
	37	0.338	0.8762	

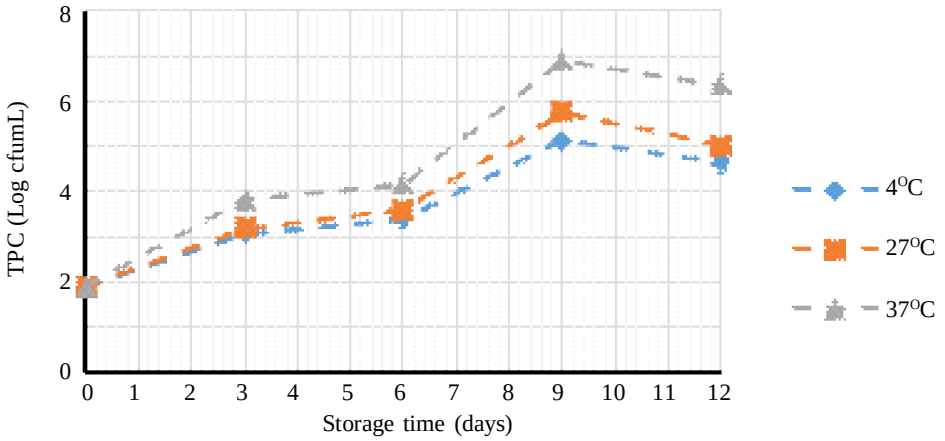

Figure 3. Changes in the total microbial value during storage

Rahayu & Nurwitri (2012) explain that microbial growth is an increase in the number of microbes or microbial cell mass, which can be interpreted as an increase in the size of microbes. Factors that can affect the growth of microorganisms in food products are intrinsic and extrinsic factors. Intrinsic factors include acidity (pH), water activity (aw), equilibrium humidity (Eh), nutrient content, antimicrobial components, and food structure. Extrinsic factors include storage temperature and humidity content around food (Arpah, 2001). An increase in the number of microorganisms is not only influenced by a decrease in the pH value or total sugar (°brix), but an increase in the TPC can also be affected by the storage temperature of the product. This is similar to the statement of Rahayu & Nurwitri (2012) that temperature is also a very important factor for microbial growth. Temperature can affect the length of the lag phase, growth speed, enzymatic activity and absorption of nutrients by microbes. The lowest temperature of microbes to grow is -34°C and the highest temperature can exceed 100°C.

Shelf Life Estimation

The Arrhenius equation can describe the correlation between changes in product quality parameters and storage temperature. This equation can be used to predict the accelera-

tion of product damage when stored at more extreme temperatures (Asiah *et al*., 2018).

Order of Reaction

The choice of the kinetics of the order of the declining reaction is done by comparing the value of the correlation coefficient (R^2) in each equation, from the zero-order reaction and the first-order reaction. A reaction order with a correlation coefficient that has a greater value is the reaction order to be chosen (Table 4).

According to Syah (2012), the types of product damage classified as zero-order reactions include enzymatic degradation, non-enzymatic browning, and fat oxidation. While the types of product damage that are included in the first-order reaction are rancidity, micro-organism growth, off-flavor production by microorganism, vitamin damage and protein quality loss. In zero-order reactions, the decrease in quality is constant, while in first-order reactions occur exponentially.

After determining the reaction order, an Arrhenius approach is made to graph the correlation between the rate of decline in product quality (Ln k) and the storage temperature (1/T) based on the selected reaction order. Then the activation energy value will be obtained for each parameter.

Critical Point

Selection of the critical parameters of shelf life is done by determining the quality parameters that have decreased the fastest during storage that is indicated by the greatest value of the correlation coefficient (R^2), then the quality parameters most sensitive to temperature changes are seen from the lowest activation energy (Ea) value.

According to Hariyadi (2019), the activation energy is the minimum energy level needed to start a change reaction. The relationship between activation energy and reaction rate is inversely proportional. The greater the activation energy, the slower the reaction rate because the minimum energy for the reaction to occur is greater.

To determine the critical parameters seen from the smallest activation energy value of each parameter, because of the smaller the activation energy, the faster the reaction rate. The activation energy value (Ea) can be calculated by multiplying the value of Ea/R, where the R-value is 1.986 cal/mol. The parameter that has the smallest activation energy value is the total microbial parameter (Table 4).

Shelf Life Calculation

In coffee beverage products, which have the smallest activation energy value found in the total microbial parameters, with the equation ln k = -1089 (1 / T) + 3.3491, where the activation energy value is 2162.75 cal/mol. This reaction equation will be used to get the k value of each storage temperature. To obtain the shelf life of mixed arabica coffee beverage products in Table 5.

In the Arrhenius method, the temperature is a very influential factor in decreasing the quality of food products which is suported by Hariyadi (2019). The higher the temperature, the higher the reaction rate.

Table 4. Activation energy values for each parameter of mixed coffee beverage products

Parameter	Arrhenius equation	Activation energy (cal/mol)
pH	ln k = -7761.4 (1/T) + 21.904	15414.14
TDS (ppm)	ln k = -1090.8 (1/T) + 7.6225	2166.33
TSS (°Brix)	ln k = -8129.7 (1/T) + 22.243	16145.58
Total color difference (ΔE)	ln k = -2774.5 (1/T) + 8.7868	5510.16
TPC (cfu/mL)	ln k = -1089 (1/T) + 3.3491	2162.75

Table 5. Predicted shelf life for each parameter

Temperature (^{O}C)	Test parameter	K value	Activation energy (cal/mol)	Shelf life prediction (days)
	Sensory	-	-	3.88
4	TPC	0.5586	0.1731	6.16
	TDS	39.8289	0.1734	4.69
	Total Color Difference	0.2924	0.4409	8.04
	pH	0.0022	1.2337	9.88
	TS	0.0008	1.2932	4.07
27	TPC	0.7551	0.1476	4.56
	TDS	53.8660	0.1478	3.47
	Total Color Difference	0.6303	0.3759	3.73
	pH	0.0189	1.0517	1.15
	TS	0.0078	1.1015	0.43
37	TPC	0.8489	0.1382	4.05
	TDS	60.5694	0.1384	3.08
	Total Color Difference	0.8494	0.3521	2.77
	pH	0.0436	0.9849	0.50
	TS	0.0187	1.0316	0.18

As the temperature increases, the damage reaction to the product is also faster so that the shelf life obtained is shorter (Table 5). At 4^{O}C the storage temperature has the longest shelf life so the coffee beverage products to get a long shelf life, should be stored at a low temperature (4^{O}C).

From the calculation of the value of k (reaction rate) and activation energy at each temperature seen in Table 5, in line with the theory that the lower the value of the activation energy, the reaction rate goes fast, with this shorter shelf life. But from the results obtained, the total sugar should have a longer shelf life compared to other parameters, due to the slow rate of decline.

According to Anagari *et al*. (2011), in determining shelf life can not only be done by one method, sensory, physical or chemical or one particular method. This is due to each product has different characteristics when it is indifferent storage conditions (temperature). As additional data, the prediction of shelf life at 4^{O}C is also carried out with a sensory test. The lowest prediction (lower) is taken it has a shelf life of 3.88 days. This beverage product is recommended to be stored at 4^{O}C. Therefore, the shelf life of this product is taken to predict the lowest shelf life for 4^{O}C temperature is 4 days.

CONCLUSIONS

The results showed that during storage of mixed Arabica coffee drinks, a pH value decreased from 5.56 to 5.42-3.67, indicating that the product was getting more acidic. The number of microbes increased, from 1.92 log CFU/ mL to 4.64-6.37 log CFU/ mL. Each parameter has a different activation energy value. The higher the storage temperature was proven to the smaller the activation energy. On the measurement of total microbes, the activation energy of each treatment temperature 4^{O}C, 27^{O}C and 37^{O}C was 0.1731, 0.1476 and 0.1382, respectively. Therefore, it was concluded to obtain a good quality storage and storage life used at 4^{O}C with a shelf life of four days.

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