Quality Deterioration and Shelf Life Determination of Purwaceng Coffee based on Packaging Variation using Accelerated Shelf Life Testing (ASLT)

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Abstract: Purwaceng coffee is a varian of coffee products that has benefits for human health. The quality of purwaceng coffee has significantly related with their shelf life. However, many purwaceng coffee producer still predicts the shelf life manually without scientific method, which has relatively low accuration. Therefore, many studies have been conducted to overcome that poblem in order to extend their shelf life. Packaging-based prediction used since that method could detemine the shelf life of the poduct adequately. The aim of this study is to analysis quality deterioration of purwaceng coffee and determine their shelf life based packaging variation. The packaging used were PAP 0.11, AF 0.05, PP 0.05, PP 0.03, and PE 0.03. The quality deterioration of purwaceng coffee was measured by 6 parameters, namely water content, water activity (Aw), weight, pH, colour, and antioxidant activity. Water content was determined by thermogravimetry method, colour by chromameter, and determination of antioxidant activity was carried out by DPPH method. Futhermore, the product shelf life test was performed using the critical moisture content method. The longest shelf life of coffee product was reached by AF 0.05 which has shelf life of 322 days and permeability value of 0.27 g H_2O/mmHg.m^2.day.

1 INTRODUCTION

Coffee is an agricultural commodities which has the most reliability in Indonesia. Coffee is not a native plant of Indonesia, but originated from the African Continent (Anonym, 1988). Purwaceng plant is an endemic species that grows in the altitude mountains of 1,800 - 3,500 m above sea level in West Java (Mount of Pangrango), Central Java (Dieng plateau) and East Java. Purwaceng seeds are expensive commodities which has high demand as the herbal medicine or functional food industry (Anonym, 2000, Rostiana, 2006). Purwaceng coffee is the product which containing a combination between coffee and purwaceng powder, as well as other additives with a percentage based on a determined formula.

The deviations in product quality from the beginning of their quality are called deterioration (Arpah, 2001). The deterioration process is caused by a reaction that starts from contacting the product with air, oxygen, water vapor, light, or due to changes in temperature. This reaction can also be preceded by physical treatments such as vibration, compression, and also abrasion.

Packaging is one determinant of product shelf life. Packaging permeability was the important factor in relation to quality deterioration and shelf life determination of product in a packaging through its critical water content. Some of common quality attributes which affected the product self life were water content, water activity, pH, weight and colour change (Brown et al., 2011). Each packaging has specific caracteristics that will affect their capacity to maintain product inside toward harsh environmental.

There were two methods for determine the shelf life of a food item, namely Extended Storage Studies (ESS) and Accelerated Shelf Life Test (ASLT) (Floros and Gnanasekharan, 1993). Extended Storage Studies is the conventional method of determining expiration by storing a product under normal conditions, then observing changes in their quality

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and shelf life. This method requires the same amount of time as the quality change, therefore, if the quality change was long, the time used for research using this model will also be long. The ESS method usually used for food products that have a shelf life less than 3 months, whereas the ASLT methods was more suitable to predict the food products that have a shelf life more than 3 months.

There are two kind of approaches for determining the shelf life with the ASLT method namely the Arrhenius approach and the critical moisture content approach. The Arrhenius approach is used for food products that are damaged due to chemical reactions which are influenced by temperature factors. The critical moisture content approach is used for food products caused by adsorption of mositure content, usually it used in dried food products (Anandito et al, 2017). Objectives of the research were to analyze the isothermic sorption curve of purwaceng coffee products, to predict the self life of purwaceng coffee in various types of packaging, and to analyze the effect of packaging on the decline in quality of purwaceng coffee

2 EXPERIMENTAL METHOD

2.1 Material

Robusta coffee roasted powder from a farmer in Gunung Kelir, Semarang. The coffee which used is robusta medium roasted. These coffee was packaged in PP 0.05 mm of thickness. Purwaceng powder was originated and produced by purwaceng farmer group at Dieng, Wonosobo. This powder also packaged in PP 0.05 of thickness. Addictive ingredient in this product is non diary creamer and sugar. The materials was sealed for further experiment. The materials were keept on room temperature in the laboratory of bioindustry, Gadjah Mada University before using.

In this study, purwaceng coffee was packaged using 5 types of packaging. There were alumunium foil (AF) (thickness of 0.05 mm), combination of poliethylene - alumunium foil - paper foil (PAP) (thickness of 0.11 mm), polipropylene (PP) ((thickness of 0.05 mm), polipropylene (PP) ((thickness of 0.03 mm), and poliethylene (PE) (thickness of 0.03 mm).

2.2 Purwaceng Coffee Production

Purwaceng coffee production process generally consists of 3 stages of production, namely the manufacture of Robusta coffee powder, manufacture of Purwaceng powder, and the mixing of ingredients. Making robusta coffee powder using a roaster and grinder with type roasting medium and fine grinding. Purwaceng powder produce by drying purwaceng plants, cleaned, and mashed using grinder to become smooth. The following step is blend and homogenize of robusta coffee powder, non dairy creamer, purwaceng powder, and sugar. The mixtures were then packaged using 5 type of packaging and kept in room temperature for further experiment.

2.3 Quality Deterioration Testing

Quality deterioration of purwaceng coffee was tested by 6 parameters. Those parameters were water content, water activity (Aw), weight, pH, colour, and DPPH antioxidant activity. Water content was determined by thermogravimetry method, Aw was measured by Aqualab Series 3 (USA), weight by analitycal balance (ACIS 600i), pH by pH meter 009 (I) A (USA), colour by cromameter (Konica Minolta FR 400), and antioxidant activity was measured by DPPH method.

The samples were stored in incubator (Memmert GmbH) at 30ºC for 90 days. This assay was carried out periodically every 15 days. Statistical test using IBM SPSS Statistic 24 was performed for the comprehensive test result from all of the assay. The statistical tests used include data normality tests, homogenity tests, and ANNOVA tests, and Kruskall Wallis test. Statistical test was used to determine the effect of packaging variations on the quality changes of product packaged. A general quality deterioration test was also used to confirm the estimated shelf life that has been determined previously.

2.4 Determination of Purwaceng Coffee Shelf Life

2.4.1 Initial Water Content (Mo) Measurement

Initial water content was determined by thermogravimetric method to evaporate the water inside product. This experimental procedure refers to the procedure of the Association of Official Analytical Chemists/AOAC (Anonym, 1995). Two grams of sample was evaporated using oven dyer at 105°C for about 6 hours, and then placed it in a dessicator vacuum for 15 minutes before weighing the dried samples using analytical balance. The assay was carried out in triplicate.

2.4.2 Isothermic Sorption Curves Measurement

Determination of moisture isothermic sorption in this study was conducted using the static thermogravimetric method, Principle of this method is to evaporate the water content when the sample in an equilibrium state. Based on Anandito et al (2017, data unpublished), the isothermic sorption curve was determined at constant temperature (30ºC). In this study, different relative humidity (RH) was achieved by using several saturated salt of NaBr, $NaNO_2$, NaCl, KCl, and $BaCl_2$, which gave a relative humidity value of 56%, 64%, 75%, 84% and 90%, respectively.

2.4.3 Packaging Permeability Test

The packaging permeability test for water vapor in this study used the ASTM E-96 procedure by using a device in the form of a WVTR (Water Vapor Transmission Rate) cup filled with 15 grams of dry silica gell and the sample of the package was placed on a WVTR dish. After that, the weight of the WVTR cup is weighed once a day for 7 days. According to the ASTM E-96 (American Method) procedure, the temperature and RH required for data collection are 30ºC ± 2 ºC and RH 50-60%. The temperature and relative humidity was controlled in an incubator.

2.4.4 Determination of Shelf Life

Determination of purwaceng coffee shelf life was carried out using the equation as follow (Labuza, 1984):

$$t = \frac{\ln\frac{(Me-Mo)}{(Me-Mc)}}{\frac{k}{x}\left(\frac{A}{Ws}\right)\frac{Po}{b}} \quad (1)$$

Components used for determine the shelf life were initial water content (M_o), critical water content (M_c), and equilibrium mositure content (M_e). These three parameters were expressed in units of g H_2O / 100 g solid. Material permeability (*k/x*) was expressed in gr H_2O/mmHg.m^2.day. The surface area of the packaging (A) is 0.00945 m^2, and the weight of the product/package was 21 grams. Saturated vapor pressure was denoted by P_o and the slope of the isothermic sorption curve was denoted by *b*.

2.4.5 Statistical Analysis

All assay were carried out in at least triplicates. Analysis of Varian (Annova) was used to analyze the significance differences of parametric data of the packaging with least significance difference (LSD) at $p < 0.05$ as a level of significance. Meanwhile, Kruskall Wallis was used to analyze the significance differences of non parametric data.

3 RESULT AND DISCUSSION

3.1 Quality Deterioration

3.1.1 Water Content Assay

Water content is one of quality parameters which has significant effect on agriculture product deterioration. The result showed that all samples has a stagnant increase of water content in general, eventhough at 90th day there was a decrease in water content in all packaging. Increase in water content among 5 packaging showed different values. The result of water content deterioration test was depicted in Figure 1.

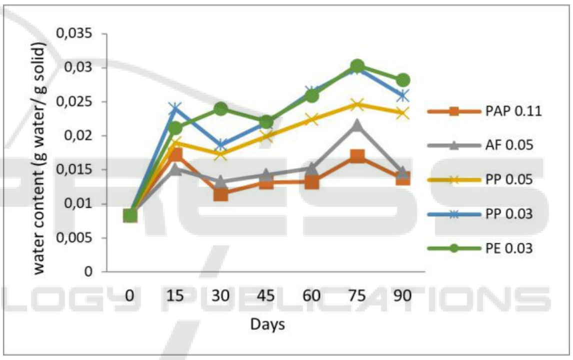

Figure 1: Quality deterioration graph based on water content parameter.

The smallest increase in water content occurred in the PAP 0.11 and AF 0.05 packaging, while the largest increase of water content occurred in the PE 0.03 packaging. This differences of water content increase may caused by the differences of the packaging nature, especially in terms of packaging permeability. Permeability of packaging materials indicate the ability of packaging materials to protect the products inside from the transpiration rate of water vapor coming from the environment. The smaller the permeability value, the better the packaging's ability to protect the product from transpiration of water vapor.

According to the water content as shown in Figure 1, AF 0.05 packaging has the lowest permeability value, following by PAP 0.11, PP 0.05, PP 0.03, and packaging PE 0.03 with highest permeability value. Rahayu and Eny (2007) state that aluminum foil (AF) packaging was better than Polyethylene as well as hand paper when used to maintain the moisture content. That was the reason that the permeability value of the aluminum foil packaging was smaller than the other two packaging. Products which packaged using aluminum foil also showed lower water content. The smaller the increment of water that enters the material, the better the packaging to use.

Based on the ANNOVA analysis, the significance value of 0.009 (<0.05) was obtained, means that the population tested was significantly different. Therefore, it can be concluded that based on water content parameters, the type of packaging significantly influences the quality deterioration of purwaceng coffee.

From the results of the Post Hoc Test by water content parameter, data groups that have different significantly was occurred in 2 pairs. Those data were the decrease in water content in PAP 0.11 - PP 0.03 and PAP 0.11 - PE 0.03 packaging. Another pairs data groups was not different significantly at all. This means that the reduction in water content in the packaging of PAP 0.11 and PP 0.03 was significantly different.

3.1.2 Weight Assay

The weight of purwaceng coffee stored in five packaging showed that all have an increased stagnant of water content in general. The product weights on 5 packaging have different values. The result of weight deterioration test was depicted in Figure 2.

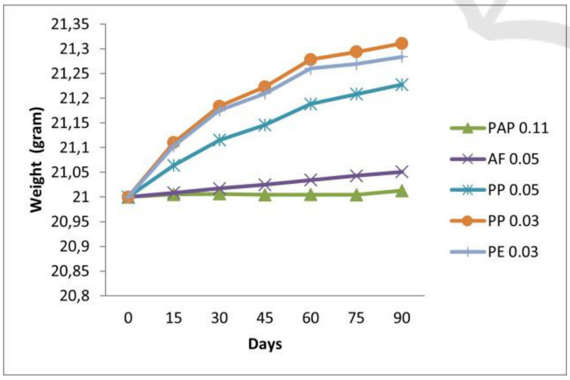

Figure 2: Quality deterioration graph based on weight parameter.

According to Figure 2, the smallest weight occurred in the PAP 0.11 and AF 0.05 packaging, while the largest weight occurred in the 0.03 PE packaging weight testing carried out for 90 days. This difference in weight value occurs may caused by the differences in the nature of the packaging, especially in terms of packaging permeability. It also shows the similarity between the results of water content and the weighting assay of purwaceng coffee.

Kruskal Wallis test was performed in this assay because the data classified into non-parametric data. Kruskal Wallis test results obtained a significance value of 0.005 (<0.05), indicated that the population data was different significantly. The results showed that the use of packaging variations has significant influences to quality deterioration of purwaceng coffee based on weight parameter.

The average weight of samples with PAP 0.11 packaging had the smallest weight changes, meanwhile samples with PP 0.03 packagimg had the highest average weight changes among 5 packaging. Based on post hoc test, it can conclude that different weights between populations occur in PAP 0.11 packaging against PP 0.05, PP 0.03, PE 0.03 and vice versa. AF 0.05 packaging was also has different significantly from PP 0.05 packaging, PP 0.03, PE 0.03 and vice versa. Population data which were not significantly different occurred in PP 0.05 packaging against PP 0.03, PE 0.03. In addition, PP 0.03 and PE 0.03 packaging also have not significant weight differences.

3.1.3 Water Activity (Aw) Assay

The existence of microorganism growth in purwaceng coffee was proven by the results of water actuvity test. The assay results showed that purwaceng coffee stored at 86% RH (Aw value of 0.86) and 90% RH (Aw value of 0.9) for 43 days has been overgrown by microorganisms (mold)

As the results of water activity assay using aqualab within a span of 90 days, the value of water activity in purwaceng coffee was under 0.4, its mean that storage of purwaceng coffee until the 90 days was not affect their quality and suitable for consumption. If purwaceng coffee consumed more than the specified shelf life limit, it can endanger consumers because the microorganisms have begun to grow. The result of water activity deterioration assay was depicted in Figure 3.

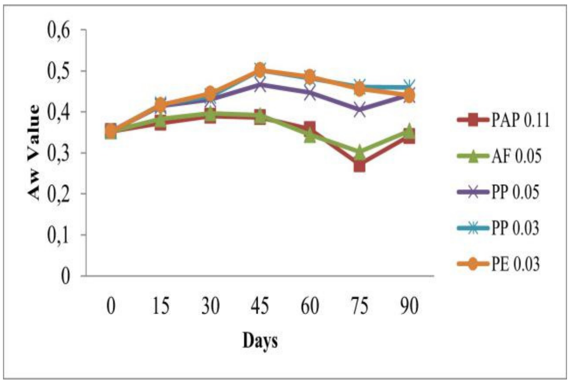

Figure 3: Quality deterioration graph based on water activity parameter.

In addition, the water activity assay was also used as a parameter for determine the effect of packaging variations on the quality deterioration. The value of Aw tends to rise, even though on the 45th day until the 90th day has decreased. In general, the greatest increase of Aw occurred in PP 0.03 packaging, while the smallest increases in PAP 0.11 and AL 0.05 packaging.

The significance value of the five packaging has a value > 0.05, its mean that the weight change data has a normal distribution. Using homogeneity test with a significance value of 0.928, the data was considered to have homogenity. Based on the ANNOVA test, a significance value of 0.000 was obtained, indicate that based on the parameters of water activity, the type of packaging significantly affected the quality deterioration of purwaceng coffee products.

Based on post hoc test, 6 pairs of data groups have significant difference. The pairs of data groups were PAP 0.11 and PP 0.05, PAP 0.11 and PP 0.03, PAP 0.11 and PE 0.03, AF 0.05 and PP 0.03, and AF 0.05 and PE 0.03.

3.1.4 pH Assay

The degree of acidity (pH) is very influential on the taste and aroma of coffee. According to Kustiyah (1985), at a pH interval between 4.9-5.2 will give a preferred coffee beverage aroma in general. The pH will increase to greater than 6.0 if the roasting imperfectly (lightly roasted). The optimum pH of robusta coffee is between 5.0-5.8, while the pH of ground coffee produced in the United States in between 4.7-5.2 (Sivetz, 1972)

According to Winarno (2004), some microorganisms such as mold and yeast can break down acids so that they will increase pH. Mold will isolate the acid and produce a final product that is alkaline due to the proteolysis reaction. In addition, the increase in pH occurs due to the formation of compounds from protein decomposition by microorganisms that are basic as ammonia. Ihwani (2008) also states that, increasing or decreasing the pH value is strongly influenced by the results of the degradation formed and the ionic balance of the protein solution. The result of water activity deterioration test was depicted in Figure 4.

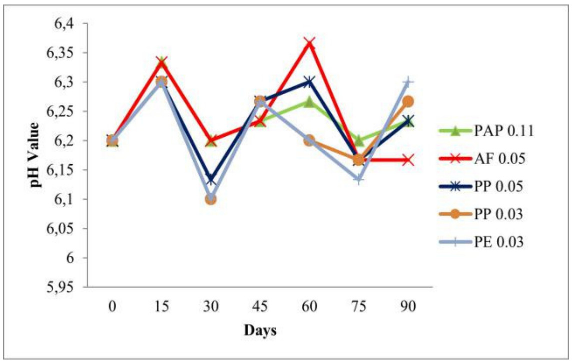

Figure 4: Quality deterioration graph based on pH parameter.

Changes that occur in this pH test, do not experience stagnation or a constant decrease. In general, the change in pH of the two packages is only at intervals 6.1 to 6.4. The pH value at the beginning of the storage period was 6.2, then changed until the last day (90th day), obtained information that the PAF 0.11 and PP 0.05 packages were able to maintain the most stable pH value and close to the initial pH quality value of 6.23. The 0.05 aluminum foil packaging has decreased pH to 6.16, while the PP 0.03 and PE 0.03 packages have increased to 6.26 and 6.3, respectively.

Statistical analysis showed that the pH change of the five packaging has a significance > 0.05 mean that the pH change was to be normal data. Furthermore, the homogeneity test obtained a significance value of >0.05 indicate that the data was homogeneous and to be further analyzed by ANNOVA. ANNOVA statistical analysis showed a significance value of >0.05, indicate that the type of packaging used was not significantly affect the pH change of purwaceng coffee.

3.1.5 Lightness

According to Bicho et al (2012), brightness /lightness (L*) decreases significantly with increasing roasting intensity, and this process affects the browning level of the product or is generally easier to understand with longer and higher roasting temperatures the product the resulting coffee is darker in color. This brownish level will also greatly affect the coordinates of a* and b*. In this research, robusta coffee produced by medium roasting was assayed their color and the result of colour deterioration test (L*, a*, and b*) was depicted in Figure 5.

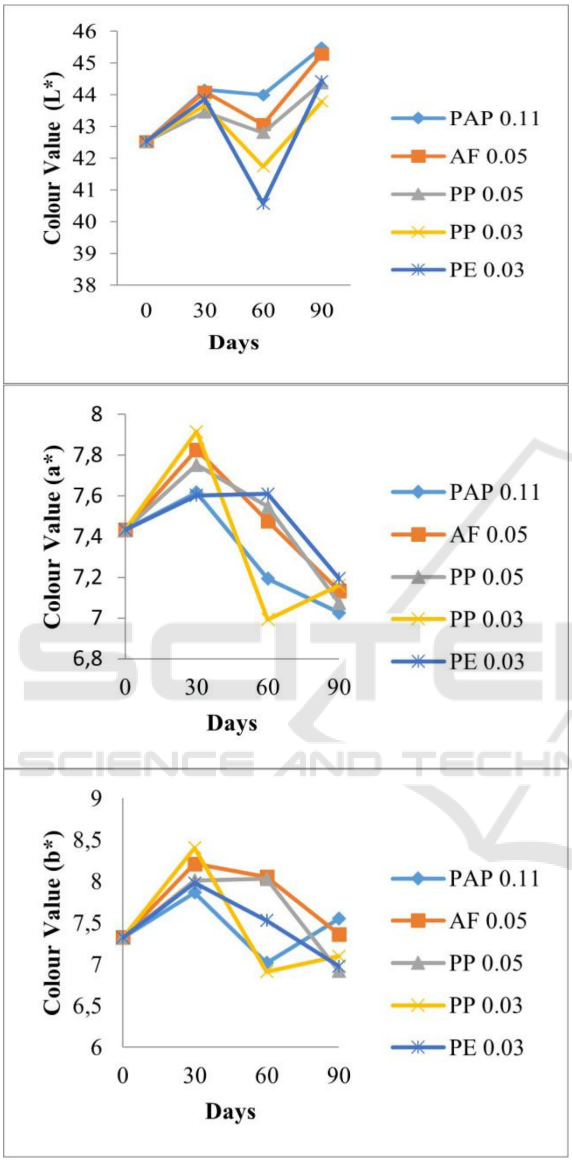

Figure 5: Colour deterioration test (L*, a*, and b*) of purwaceng coffee samples.

Results of the study found that the value of L* was in the interval 41-46 in five packaging. This indicates that purwaceng coffee has an L* value that almost same as the L* results in the study of roasted medium robusta coffee. The value of a * obtained was in the range of number 8, it has similarities to the previous studies. However, the value of b* was lower than the previous research.

3.1.6 Antioxidant Activity

DPPH (2.2-diphenyl-1-picrylhydrazyl) scavenging activity test was conducted by comparing the pure antioxidant/strong antioxidant. The parameter of the DPPH method is the 50% inhibition concentration (IC_{50} value) or the concentration that can reduce free radical activity by 50% (Widyasanti et al,, 2016). A compound classified into very strong antioxidant activity if the IC_{50} value is less than 50 ppm, those belong to strong group have the IC_{50} value in between 50-100 ppm, and those belong to moderate group have the IC_{50} value in beetwen 101-150 ppm, the group is weak if the IC_{50} value is between 150-200 ppm, and the group antioxidants are very weak if the IC_{50} value >200 ppm (Molyneux, 2004). Vitamin C used as the comparative antioxidant (positive control) which has an DPPH antioxidant IC_{50} value of 6.0674 ppm. Its mean that DPPH scavenging activity of all samples were much lower than vitamin C. The antioxidant activity (IC_{50} value) of purwaceng coffee in five type of packaging was shown in Figure 6.

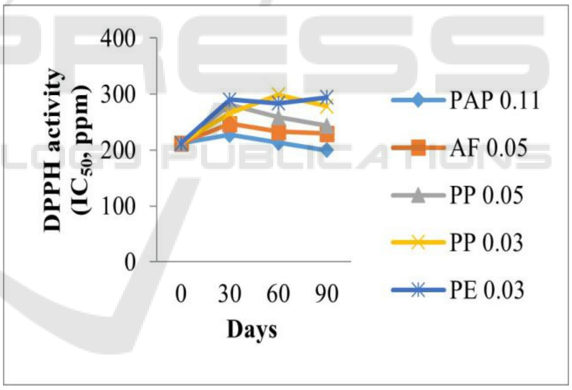

Figure 6: DPPH scavenging activity (IC_{50} value) of purwaceng coffee samples.

The changes in the value of the greatest antioxidant levels occur in PE 0.03 packaging, then in PP 0.03 packaging, and PP 0.05 packaging. On PAP 0.11 and AF 0.05 packages, the change in antioxidant activity was smaller than the previous three packages. The relationship between IC_{50} concentration values and the ability of packaging to maintain product quality is the higher the IC_{50} concentration value, the worse the packaging is in maintaining product quality. This study shows the antioxidant value of purwaceng cream coffee >200 ppm. This can be interpreted that the antioxidant value of purwaceng coffee is classified as very weak.

3.2 Determination of Purwaceng Coffee Shelf Life

3.2.1 Permeability of Packagings

Five packages were tested their permeability values. As shown in Table 1, each packaging have different permeability values. The packaging that has the lowest / smallest permeability in this study is AF 0.05 with a permeability value of 0.249 g / mmHg.m^2.day, while the packaging that has the highest permeability is the PE 0.03 packaging with a permeability value of 0.465 g / mmHg.m2.day. In general, the order of 5 packages from the smallest permeability to the largest permeability were AL 0.05, PAF 0.11, PP 0.05, PP 0.03, and PE 0.03, respectively.

Table 1: Packaging permeability value.

Packaging Type	Area (m^2)	Slope	Permeability (g/mmHg.m^2.day)
PAP 0,11	0,001555	0,0092	0,268211858
AF 0,05	0,001555	0,0082	0,249188856
PP 0,05	0,001555	0,0128	0,373164324
PP 0,03	0,001555	0,0144	0,437599942
PE 0,03	0,001555	0,0153	0,464949938

3.2.2 Isothermic Sorption Curve

The models used to determine the shape of the isothermic sorption curve are very diverse. The model to be selected is the one with the smallest Mean Relative Determination (MRD) value. The Oswin model was used to create an isothermic absorption curve because it has the smallest MRD value compared to the other 5 models, as shown in Table 2.

Table 2: Mean relative determination.

Model	Equation	MRD
Hasley	$\log\left(\ln\left(\frac{1}{aw}\right)\right) = -1{,}241 - 0{,}672 \log Me$	8,568
Chen – Clayton	$\ln\left(\ln\left(\frac{1}{aw}\right)\right) = 0{,}594 + 4{,}814Me$	41,636
Henderson	$log\left(\ln\left(\frac{1}{1-aw}\right)\right) = 0{,}542 + 0{,}406 \log Me$	10,170
Caurie	$\ln Me = 7{,}610 + 7{,}205aw$	13,522
Oswin	$\ln Me = 1{,}279\ln\left(\frac{aw}{1-aw}\right) - 3{,}765$	8,360
Guggenheim-Anderson-de Boer (GAB)	$Me = \frac{0{,}0198\, aw}{(1 - 1{,}048)(1 + 1{,}068aw)}$	55,357

Furthermore, Oswin model is used to determine the equilibrium water content at A_w of 0.6. Based on the substitution results above, the equilibrium water content value was 0.0389 gam water/gram solids. The isothermic absorption curve of the Oswin model was depicted in Figure 7.

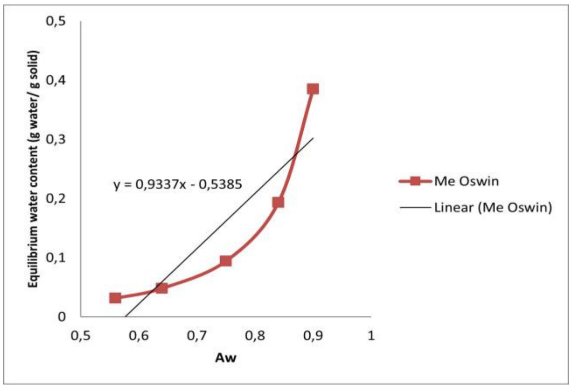

Figure 7: The isothermic absorption curve of the Oswin model.

According to Labuza (1984), the value of the slope on the sorption curve is determined in the linear region. The slope of the isothermal sorption curve is the value of the straight-line slope of the linear region which passes the water content at different relative equilibrium values. The slope value of the isothermal sorption curve in this study was 0.9337.

3.2.3 Estimation of Purwaceng Coffee Shelf Life

By using equation 1, the self life of purwaceng coffee in five types of packaging could be determined. The shelf life of purwaceng coffee resulted from those equation was depicted in Figure 8. The longest shelf life was reached by purwaceng coffee packaged using AF 0.05, with the self life estimation of 322 days. Conversely, purwaceng coffee packaged using PE 0.03 has the shortest self life estimation. Purwaceng coffee packaged using PAP 0.11 has a relatively longer shelf life than those packaged using PP 0.05, PP 0.03, and PE 0.03 as well.

Comparing with the other research of shelf life in similar product, durian flavored coffee products has a shelf life of 199 days (Nirmala, 2017) and brand instant coffee XYZ has a shelf life of 21 months or 632 days (Wijaya, 2007) . The shelf life of purwaceng coffee packaged by AF 0.05 was longer than those of durian flavored coffee and shorter than those of XYZ instant coffee. This may caused by many factors, one of which was the packaging used. XYZ brand instant coffee packaging in the form of metalized film was much better in maintaining the quality of coffee products, therefore their shelf life was longer.

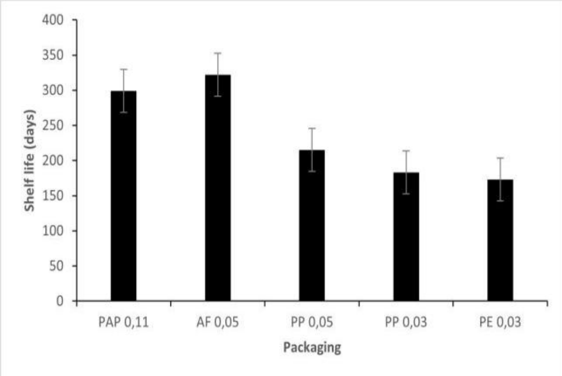

Figure 8: Shelf life estimation of purwaceng coffee using five type of packaging.

4 CONCLUSIONS

Purwaceng coffee packaged by AF 0.05 has the longest shelf life estimation (about 322 days), compared to the other four packaging. By using water content, water activity, and weight parameters showed that the type of packaging used has a significant effect on quality deterioration of purwaceng coffee.

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