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Differences Phsyco-Chemical Characteristic of Repeatedly Frying Oil Used for Banana and Chicken

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***Abstract*—One of the habits in the food processor is the use of cooking oil repeatedly. The long-term and repeated use of cooking oil causes a change in the physicochemical properties of oil and can affect the quality of food products produced. This study focused on the physicochemical properties of repeated frying oil in two types of foodstuffs, namely banana, and chicken. The research variables that represent physicochemical properties are free fatty acid, smoke point, and color. Free fatty acid was measured using titration method, and the smoke point was measured using Cleveland method. The color was evaluated by UV-Vis Spectrophotometric method. The results showed that the repetition deep frying for chicken and banana increased free fatty acids, decreased the smoke point and changed the color of cooking oil. There was a significant change of physicochemical properties in chicken and banana repeatedly frying oil. The first frying of chicken causes a significant change in the oil properties and the third frying of banana shows a significant change in oil properties. This study revealed that the free fatty acids of oil increased ranging from the first to the fifth frying either oil for the fried bananas or the fried chicken. This study also exposed that the chemical characteristic of fried chicken oil was higher than fried banana oil. The smoke point of fried banana oil is higher than fried chicken oil. The deep of fried banana oil has similar absorbance value in the first frying. The value increased based on increasing the frequency of frying repetition.**

***Keywords*— free fatty acid; smoke point; frying oil.**

I. INTRODUCTION

The habit of reusing cooking oil austerity reason can cause a health problem. The repeated use of cooking oil will change the physicochemical properties of the oil. Visually, the color of the oil will be more dirty or brown due to the browning reaction. Also, due to the polarization of fatty acids, the viscosity of the cooking oil is higher. Essential quality characteristics of cooking oil are high oxidation stability, high smoke point, low foam, low melting point, color and good nutritional value [1], [2].

Cooking methods by immersing foods in hot fat (deep frying method) are used more often than in shallow fryers. Deep fat frying is the process allows the food to be immersed in hot oil at a temperature of 150^{o}C - 190^{o}C. In this process, oil acts as a heating conductor from the media to the food products [3]. Deep fat frying contributes to the texture and flavor of fried foods. During frying occurs various chemical reactions such as oxidation, hydrogenation, isomerization, polymerization, and crystallization can produce free fatty acids, mono and *diacylglycerol*, and the formation of monomers, dimers, and polymers that can affect the appearance, aroma, and taste of fried foods [4], [5].

The repeated heating process of oil at high temperatures and long enough time will produce polymer compounds in the form of solid in oil (*acrolein*) [6]. The more repetitions of frying, the higher the level of oil damage. The use of oil many times causes the oil to be quickly smoky or foamy and change the color. Consequently, the color and flavor of fried foods will not be preferred, the structure and appearance of less attractive and the image of unpleasant taste and smell. Furthermore, repeated frying oil will also decrease the nutritional value and damage human health.

Hydrolysis is chemical reactions that occur in oil due to heating [7], [8]. Hydrolysis occurs in cooking oil due to the triglycerides content that reacted with water (H_2O). Triglyceride in oil is formed as a result of condensation of one glycerol molecule with three fatty acid molecules. The higher the water content of food, the condensation is faster. Furthermore, the faster hydrolysis reaction takes place in the high water content of the food. Due to heating, the compounds react with water molecules contained in fried materials.

The oxidation process of oil heating occurs in two forms: autoxidation and thermal oxidation. The *autoxidation* process occurs due to the reaction of cooking oil with oxygen even without heating [10]. The incorporation of oxygen molecules with unsaturated fatty acids can produce an oxidative reaction of the initiator. In addition, also in the healing process occurs "auto-oxidation" or the formation of hydrocarbons, aldehydes, and ketones which cause a rancid odor to oil and food [11]

While the process of thermal oxidation occurs due to heating at high temperatures, and there is direct contact with oxygen. *Hyperoxide* is the primary product of unsaturated fatty acid autoxidation is stable at moderate temperatures unstable at temperatures above 80^{o}C. *Hyperperoxide* compounds cause odor changes in oil [12][13]. The heating process of cooking oil also causes fatty acid slicing. The broken components will bind again with other components and form large components but with different sizes from the previous conditions. Changes in the size of the bonds cause a change of oil color. The breaking and forming of new components are called polymerization [14]. Consumption of foods fried with reheated oil in production for the long term can affect human health. The content of free fatty acids and the occurrence of free radicals can cause pathological disorders such as hypertension, diabetes and vascular inflammation[15].

The using of repeatedly frying oil should be prevented in anticipation of disease risk for humans. In Indonesia, various types of fried foods are sold as street food vendors. Types of favorite snacks that are always found in almost all major cities are fried bananas, fried *Tempe,* and fried tofu. Also, fried chicken or crispy chicken culinary business is also overgrowing. The price of this food is relatively cheap and delicious taste causes most people of Indonesia like fried food.

Changes in the characteristics of oil due to recurrent heating by the deep frying method are the focus of this study. Measurements of free fatty acids, smoke points and oil color on heated oil are the variables of this study. The results of this study became the basis of consideration in the utilization of cooking oil and food produced quality and does not contain harmful components for human health.

II. Material and Method

A. Material

The material used is palm oil with the characteristics by SNI-3741-1995 (Table 1). Foodstuffs fried as test materials were banana (vegetable food) and chicken (animal food). The characteristic of the two kinds of food is represented in Table 2. The kind of banana was *kepok* banana (*Musa acuminate a balbisiana Colla*) which has carbohydrate content as 0.22% and fiber as 2.6%. The weight of banana for each is 100 gr – 150 gr [16].

Other complementary materials are wheat flour, seasoning flour. The research material that works in the measurement process is the standard solution, NaOH solution, neutral alcohol, and pp indicator. Provision of fried foods by specific compositions of *kepok* (250 g), wheat flour (25 g), water (65 ml). The composition of frying pan fried chicken (crispy) that broiler chicken (250 g), flour spices (25 g), water (25 ml). The volume of oil for frying as much as 3.5 liters with the same weight of the food.

TABLE I
PALM OIL CHARACTERISTIC

Criteria	**Standard**
Smell And Taste	Normally
Color	Light color and clear
Water Content	Max 0.3%
Specific Gravity	0.900 gr/L
Free Fatty Acid	Max 0.3%
Peroxide Value	Max 2 Meg/Kg
Iod Value	45 – 46
Saponification Value	196 – 206
Refractive Index	1448 – 1450
Metal Contamination	Max 0.1 mg/kg

TABLE II
FOOD CHARACTERISTIC

Characteristic	Composition (%)	
	Banana	Chicken
Water content	65.9	74.9
Fat	0.33	15.06
Protein	1.09	18.6
Ash	0.82	0.79
Glucose	4.98	0.4

The composition of chicken fatty acids consists of saturated fatty acids 28 - 31% and unsaturated fatty acids comprising oleic acid 47 - 57%; linoleic acid 14 - 18%; *linolenic* acid 0.7 - 1.0%; and *arachidonic* acid 0.3 - 0.5%

B. Method

The frying method was deep fat frying. The process of frying food begins by inserting fresh cooking oil into the frying kettle as much as 3.5 liters, then the kettle is heated to 180^{o}C. The ingredients are fried until cooked for 10 minutes and are attempted to stir to minimize the convection flow in the oil and oxidation reaction due to the aeration process. The research treatment was repeatedly frying for two kinds of food. The kettle are represented on Fig.1.

Fig.1 Preparation of the kettle for the frying process

The repeating frying was first frying, second frying, third frying, forth frying and fifth frying. The oil used for frying is the same oil (not replaced and not increased the fresh oil). Repeat frying is done five times with the same frying time. A sampling of cooking oil to analyze the physicochemical properties of 200 ml. The parameters analyzed were: free fatty acid, smoke point, and color

1) Free Fatty Acid: The oil sample (10 gram) was added to Erlenmeyer and added 50 ml of 95% neutral alcohol (see Fig 2).

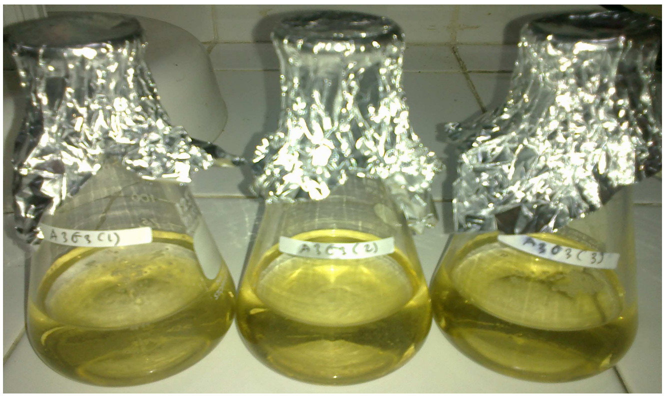

Fig.2. Free fatty acid test

The sample is heated to boiling at 40°C. After the sample was cold, the specimen was added 2 ml of phenolphthalein (pp) indicator. Titration with standardized 0.1 N NaOH solution until pink is achieved and not dissipated for 30 seconds (Figure 3)

Fig 3. The result of oil titration

$$\%FFA = \frac{mlNaOH \times NNaOH \times BMPalmitateAcid}{SampleWeight(g) \times 1000} \times 100 \quad (1)$$

% FFA : Free Fatty Acid Content
ml NaOH : Titration Volume NaOH
N NaOH : Molarity of solution NaOH (mol/l)
BM Palmitate Acid : The molecular weight of *palmitic acid* 256 g/mol

2) Smoke Point: The smoke point is measured by the open "*Cleveland*" trophy method. (Fig. 4).The oil sample is put in a 25 ml cup and placed on a hotplate. The thermometer is inserted into the center of the glass in a vertical position. Trophy glass is heated to a temperature of 40 - 50^{o}C. Smoke points are observed when oil samples emit a thin, bluish smoke that flows continuously [17].

Fig. 4 Trophy glass for measure the smoke point

3) Color: Measurement of oil color based on spectrophotometric reading or absorbance value. The measurement method is the *spectronic apparatus* 20. The apparatus is turned on for ± 15 minutes. Standard wavelength measurement solutions ranging from 400 nm to 600 nm result in absorbance values. Provision of cooking oil samples by first shuffling before being put on the cuvette. The next sample is inserted into *spectronics* 20 to obtain an absorbance value. Absorbance readings obtained color data on cooking oil (AOCS). The higher the absorbance value, indicating the darker the sample color. [18].

4) Data Analysis: Analysis of the psycho-chemical properties of repeated frying oils is described in table 3.

TABLE III
ANALYSIS METHOD

Variable	Method	Indicator
Free Fatty Acid	Titration	FFA (%)
Smoke Point	Cleveland	Smoke Point (oC)
Color	Spectrophotometry UV-Vis	Absorbance value

The data obtained were analyzed using descriptive analysis and variance analysis (ANOVA). The SPSS program version 17 is used as analytical tools based on Randomized Block Design with three repetitions.

III. RESULTS AND DISCUSSION

A. Free Fatty Acid

Determination of free fatty acids of oil through the amount of free fatty acids was formed in the hydrolysis and oxidation processes. The result of free fatty acid analysis on fresh oil (oil before use for frying) as control around 0,043%. The value of free fatty acid increase become 0.176% in the oil after using in deep fat frying bananas. Furthermore, this value increases to 0.181% on the second frying oil. The value of free fatty acids is higher in oil that has been heated four and five times (Fig.5).

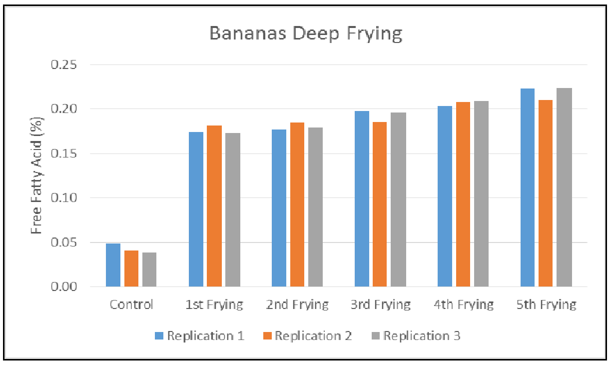

Fig. 5 The free fatty acid in the banana deep-frying process

The value of free fatty acids on the fifth frying around 0.218% and indicates that the cooking oil was a feasible value based on the maximum requirements of the Ministry of Industry in SNI-3741-1995. Free fatty acids of oil used of chicken frying in the first treatment around 0.194%. The value increased to 0.208% in the second treatment. Furthermore, in the fifth treatment, free fatty acid is 0.233% or more than the maximum standard of free fatty acid. (Fig.6).

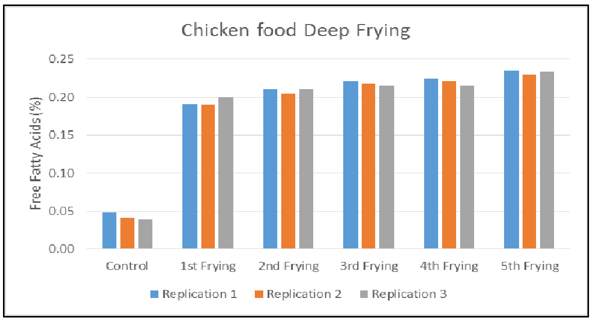

Fig. 6. The free fatty acid in the chicken deep-frying process

The comparison between two kinds of food processing results that the free fatty acid content in chicken frying oil is higher than oil from banana frying. The relatively higher free fatty acid content in chicken frying oil is caused by the high water content in the chickens. Consequently, the hydrolysis process is higher. The water content of the banana is lower and caused less hydrolysis. Water contained in the food will easily make the fatty acid bond to be short with hydrolysis. Various levels of free fatty acids are affected by the evaporation and neutralization of free fatty acids from fried foods. Free fatty acids contained in cooking oil has been used for frying and the more frequently used then the higher the content of free fatty acids. Free fatty acids levels in oil are used as an indicator of damage to used cooking oil. The process of hydrolysis of vegetable oil is increased due to the increase in temperature and with the presence of water in fat. [15], [16].

Table 4 shows the result of the statistical test (P> 0,05) that indicate that free fatty acid oil in fried chicken processing is significantly different with fresh oil. The repeatedly frying oil for a fried banana on the first and second process does not differ significantly with control treatment.

TABLE IV
STATISTICAL TEST RESULTS OF OIL-FREE FATTY ACID CONTENT OF FIED BANANA AND FRIED CHICKEN

Treatment Level	**Free fatty acids Deep Frying Oil of banana fried (%)**	**Free fatty acids Deep Frying Oil of fried chicken (%)**
Control	0.043*	0.043**
1st frying	0.176tn	-0.194**
2nd frying	0.180tn	-0.208**
3rd frying	0.193**	-0.218*
4th frying	0.207**	-0.220**
5th frying	0.218*	-0.233**

(^{in}) not significant (**) very significant (*) significant

The data in Table 4 shows that free fatty acid content increased from 0.043 - 0.218% (oil from frying bananas) and 0.043 - 0.233% (chicken frying oil). Providing the oil is heated at high temperature, some oxidized fatty acids have increased concentration, and the process will change the character of the oil. The rate of change in oil properties depends on the frequency of use, the type of frying material, the heating temperature and the time of frying. [17], [21].

Free fatty acids contained in the oil of fried banana and chicken results due to the hydrolysis process during frying in the presence of heat treatment. Hydrolysis occurs because of chemical reactions between water, steam, and oxygen in cooking oil and food [19]. When the ingredients are fed into hot oils, the water contained in the foodstuff comes out, and the oil enters the fried food. The exchange process between water and oil breaks the triacylglycerol ester bond and produces in and *monoacylglycerol*, glycerol, and free fatty acids. The content of free fatty acids in cooking oil has increased along with the repetition of frying, and the value of free fatty acids shows the quality of cooking oil. During deep frying, there is a decrease in oil quality due to fat oxidation. The heat treatment of deep-frying causes fat oxidation which can result in increased free fatty acids [20].

B. *Smoke Point*

The heating process of oil will lead to the occurrence of smoke due to the decomposition process of free fatty acids and other volatile components. The temperature when the oil produces a smoke constant over the warming is a smoke point [13]. The smoke point of palm oil decreases from 228°C to 207°C (oil from banana frying) and from 228°C to 201°C (chicken frying oil) after five repetitions of frying pan (Fig 7 and Fig 8). Fresh oil spots (control) is very high, then decreased from the 1st frying until the fifth frying both for banana frying process and the fried chicken process.

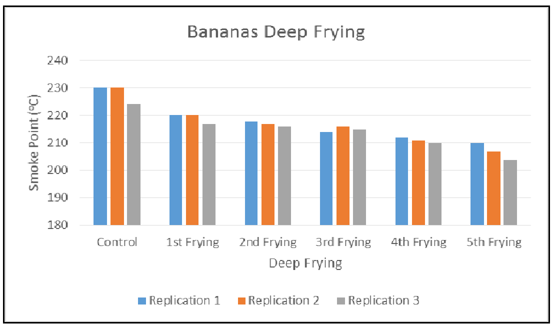

Fig. 7. The smoke point oil of banana deep frying process

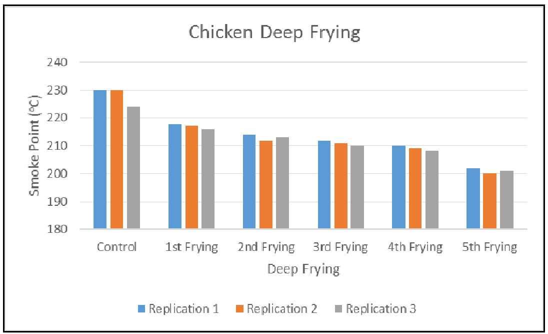

Fig. 8. The smoke point oil of chicken deep-frying process

Water, free fatty acids, and oxidation degradation products are volatile compounds that affect the fumes of cooking oil. The more volatile concentrations, the lower the smoke point of the oil [22]. The water content of foodstuff affects the decrease in oil smoke point. The more water contained in the foodstuff, the smoke point will be lower. This is caused by the process of discharge of water from the food that causes smoke. The water content in the chicken is higher than the banana, so the hydrolysis reaction occurs more and more in the fried chicken that causes the formation of much smoke. The frying banana process produced little hydrolysis reaction, and the smoke is also formed slightly. The result of a smoke point on the frying oil of two types of food is also related to the content of free fatty acid. The relationship between free fatty acids and smoke points is shown in fig 9.

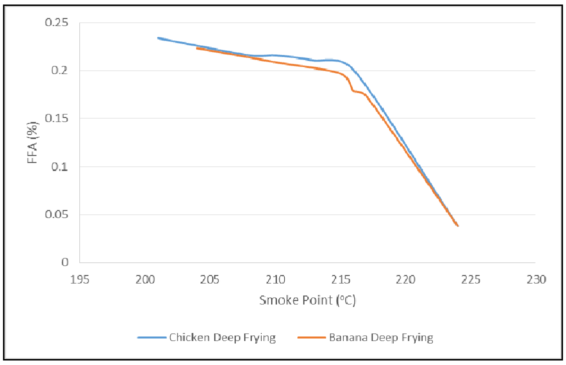

Fig. 9. The relationship between increasing of free fatty acids and decreasing smoke point

The statistical test shows that the smoke point of oil used fried chicken is significantly different with fresh oil. The difference is very evident in the first frying pan in the fifth fryer. The smoke point of banana frying oil is different significantly with fresh oil in the third frying. Even in the fifth and fourth frying, there is a very significant difference between used oil and fresh oil. (Table 5).

TABLE V
STATISTICAL TEST RESULTS OF OIL-FREE FATTY ACID CONTENT OF FIRED BANANA AND FRIED CHICKEN

Level Treatment	Smoke Point Deep Frying Oil of fried banana (oC)	Smoke Point Deep Frying Oil of Fried Chicken (oC)
Control	228.0**	228.0**
1st frying	219.3tn	216.7**
2nd frying	217.3tn	213.3**
3rd frying	214.7*	211.3**
4th frying	211.,3**	209.3**
5th frying	207.3**	200.7**

(in) not significant (**) very significant (*) significant

The decreasing of the smoke point in the oil is regarding the increase of viscosity. Food products fried with high viscosity oil will change the taste of food or cannot be accepted *organoleptically*. The viscosity changes in oil appear on the dark oil color and the increase in foam. The rate of change depends on the composition of the oil, the temperature and time of the frying pan, continuous or discontinuous frying, the type of fried food and freshness of cooking oil added during the frying pan [23], [24].

C. *Color*

Fresh cooking oil is yellow clear, and after the heating the oil color becomes dark. Carotenoids are substances that affect the color of fresh oil. This substance evaporates at the beginning of the frying process and after that changes the color of oil due to the degradation of *tocopherol* (vitamin E) [25]. The result of color measurement of fresh oil and frying oil is expressed in an absorbance value. Fresh oil gives an absorbance value of 0.50 (bright yellow).

The deep-frying oil used for banana has similar absorbance value in the first frying. The value increased is matched with the increasing of frying the repetition. The highest absorbance value of the frying oil is 0.69 in the fifth frying. A similar trend with the characteristics of chicken frying oil, the more repetition of frying the highest value of absorbance. However, the increasing value was very sharply and reached an absorbance value of 3.00. (Fig. 10 and Fig.11).

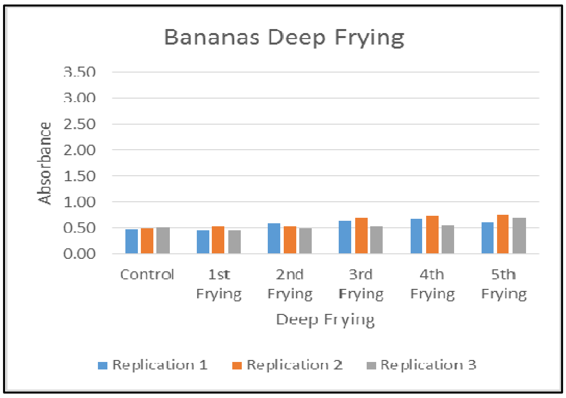

Fig. 10 The absorbance value of bananas deep frying oil

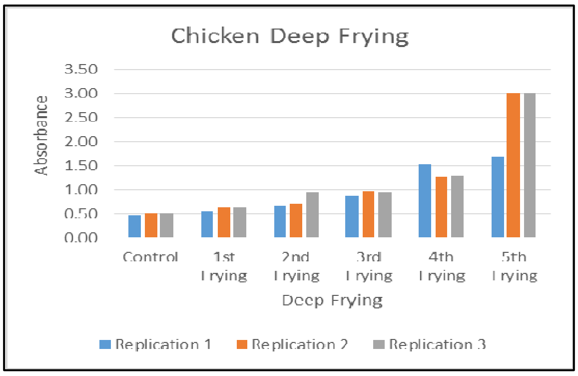

Fig. 11 The absorbance value of chicken deep-frying oil

The oil color equivalent to 3.00 absorbance value is rather dark. The color of the heated oil turns slightly darker. The change of color indicates a change in the chemical composition of the oil. The color degradation that occurs during the frying process is a result of high-temperature usage and component contamination of fried foods. Chemical reactions between foodstuffs and the oxidizing components and proteins or amino acids cause a color change in oil.[26], [27]. Table 6 shows a statistical test of the difference in absorbance values between the properties of oil that have repeatedly been heated with oil of fresh oil properties.

Table 6 shows that the absorbance deep-frying oil of banana fried for five-level treatment. The similar color with the fresh oil or the difference between oil heated characteristic and fresh oil were not significant. While the difference of absorbance of oil used fried chicken with fresh oil was very significant. The result of the analysis indicated that the frying process banana did not cause the color change. Otherwise, the frying process of chicken caused the color change.

TABLE VI
STATISTICAL TEST RESULTS OF OIL-ABSORBANCE VALUE OF FRIED BANANA AND FRIED CHICKEN

Level Treatment	Absorbance Deep Frying Oil on banana fried	Absorbance Deep Frying Oil on fried chicken
Control	0.496tn	0,.96**
1st frying	0.494tn	0.04**
2nd frying	0.536tn	0.777tn
3rd frying	0.629tn	0.929**
4th frying	0.658tn	1.358**
5th frying	0.689tn	2.564**

(in) not significant (**) very significant (*) significant

The color change of oil during frying occurs due to oxidation, polymerization and other chemical reactions. The oil color change from bright yellow to dark brown due to the carbonyl component of unsaturated fatty acids and nonvolatile decomposition in fried products containing carbonyl groups in the presence of heating. The chicken frying oil is seen to have a higher changing of absorbance value than banana frying oil. The changing caused contamination of fried food and additional ingredients given before frying. Chemical reactions between foodstuffs and the oxidizing components and proteins or amino acids cause a color change in oil. Several previous studies have revealed the causes of color change in oil during heating. The color changes of oil occurred due to the increasing of oil hydrogenation and the increasing of frying time. Furthermore, the formation of the color of the cooking oil is influenced by the type of foodstuff. During frying at high temperatures, the color component has increased color change [18], [28], [21].

D. The Changing of Physical-Chemical Characteristic

Changes in the physical properties of Deep Frying Oil chemistry are summarized in Table 7. The color change indicates a change in a review. The high water content in chickens is the cause of changes in the physical properties of the oil. The point of oil smoke decreases due to the increase in the hydrolysis reaction during the first frying. Different conditions for frying banana. Decreasing smoke points occurs in the third frying pan or hydrolysis, which occurs smaller during frying.

TABLE VII
THE SUMMARIZE OF PHYSICAL-CHEMICAL CHARACTERISTIC

Repeated Deep Frying Oil Characteristic		Foodstuffs	Control	Frying				
				1st	2nd	3rd	4th	5th
Physical	Smoke point	Banana						
		Chicken						
	Color	Banana						
		Chicken						
Chemical	Free Fatty acids	Banana						
		Chicken						

The results of this study illustrate that banana frying using oil repeatedly for two times did not change the physicochemical properties of cooking oil. Thus, the food produced is safe for human health and does not change the color and taste of food. While on chicken frying, the oil cannot repeatedly be used, or oil can only be used once. The changes in the chemical properties of oil indicated degradation of oil. The risks of human health problems are caused by unhealthy food consumption. Hypertension, cancer, and disturbance of the human circulatory system are health risks. The using of cooking oil correctly can improve the quality of human health.

IV. CONCLUSIONS

The free fatty acids of oil increased from the first to the fifth frying both of oil for the frying of bananas and the fried chicken. The chemical characteristic of chicken frying oil was higher than banana frying oil. The smoke point decreased due to the heating of oil. The smoke point of banana frying oil is higher than the smoke point of chicken frying. The deep-frying oil used for banana has similar absorbance value in the first frying. The value increased is matched with the increasing of frying the repetition. However, the characteristics of chicken frying oil, the more repetition of frying the highest value of absorbance. Based on statistical analysis indicate that the first frying of chicken causes a significant change in the oil properties while the third frying of banana led to the significant change in oil properties.

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