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Effect of vacuum frying fresh and pre-chilled tamban (*Sardinella spp.*) on the quality evaluation of palm oil

K.L. Cabillon *, Z.A. Bao-as, C.H.V. Piloton, C.M.V. Alsado

Department of Food Science and Technology, College of Arts and Sciences, Mindanao University of Science and Technology, Cagayan de Oro City, Philippines

Abstract: Vacuum Frying, operating under lower temperature, has lesser adverse effect on the quality on the oil used as cooking medium. This study aimed to evaluate the quality of palm oil used in vacuum frying pre-chilled Tamban (*Sardinella spp)* at 110˚C for 30 minutes in comparison to fresh fish directly fried after cleaning. Palm oil was used until fifth frying containing 3kg fish/batch and was evaluated in terms of: Free Fatty Acid and Peroxide Value. Odor and color were evaluated using sensory evaluation. Results showed that there is a gradual increase of quality indices values up to the fifth frying. FFA obtained were 0.26mg KOH/g Oil (Fresh fish) and 0.31mg KOH/g Oil (Pre-Chilled fish) compared to 0.6mg KOH/g Oil standard value, PV reached 18.7meq/kg (Fresh fish) while 9.62meq/kg (Pre-Chilled fish) compared to 10meq/kg standard value. There is also an increase in the intensity of the sensory attributes of oil as it is subjected to subsequent frying. This study confirms that vacuum frying slows down the quality degradation of palm oil in frying fresh and pre-chilled fish. Moreover, the use of pre-treatment–chilling for 12 hours at 5˚C-7˚C, extends the rancidity point of palm oil with basis on the physico-chemical parameters tested.

Key words: Pre-treatment method; Fish processing; Rancidity point

1. Introduction

Philippine sardine biodiversity is one of the front runners in the world, which includes fresh water sardines species. Sardines contribute to a large portion of the fish catch across the country, and became a major source of animal protein for the Filipinos (Wilette et al., 2011). Hence, the need to utilize abundant fish supply and further maximize food production methods with considerations on the involving factors which influences its affectivity and efficiency.

Frying is a process which leads to sterile and dry product with relatively longer shelf life. During processing, food is immersed in an oil bath at a temperature above the boiling point of water. This method is usually performed at high temperature about 180˚C and under atmospheric pressure. Fat and oil decomposition products have been associated with adverse health effects when fried oil degraded with continued use (Taylor et al., 1983). Repeated use of oil stimulates formation of compounds which poses adverse effects and possible hazards to human (Sanibal, 2004). The loss of quality of food and oil which is harmful to human health is caused by the degradation of structure attributes to the atmospheric oxygen reacting with lipids and other organic compounds (Bhattacharya et al., 2008).

Frying temperature and time, frying oil, antioxidants and the type of fryer affect hydrolysis, oxidation, and polymerization of oil during frying (Choe and Min, 2007). Low frying temperature and minimal exposure to oxygen contributes to the slower rate of deterioration of the oil and the product itself (Kusucharid et al., 2009). Hence the use of vacuum frying method, it is has less adverse effect on the quality of oil (Kato, 1991).

Vacuum frying is a process whereby food is heated and cooked under reduced pressure that results to the lowering of the boiling points of the frying oil used as cooking medium and the water in food (Troncoso et al., 2009). Water from food is immediately removed as it reaches a lower boiling point since the food is heated under reduced pressure. Moreover, the boiling point of frying oil is also lowered (Hidaka et al., 1991). Increased boiling points result to decreased frying time due to the increased rate of heat transfer to the interior of the food (Meltzer et al., 1981). Hence, food's natural color and flavor and the quality of frying oil is preserved (Kato, 1991).

But even with this advantage, oil exposure to temperature around 90-100˚C (Setyawan et al., 2013) might still promote the degradation of the frying oils (Meltzer et al., 1981). In the frying process, the factors air, water and light causes the thermal, oxidative and hydrolytic decomposition of oil and fats forming hydroperoxides and primary oxidation products. The instability and decomposition of the peroxides leads to the

* Corresponding Author.

formation of free radicals (Shyi-Liang, 1998). Moreover, oxidation of oil is hastened by the presence of oxygen. Oxygen reacts with the unsaturated fatty acids to form oxidation products and thereby causing oil rancidity (Shyu et al., 1998).

This study was conducted to evaluate the quality of oil used in vacuum frying tamban (*Sardinella spp*). Specifically, it aimed to evaluate the palm oil in terms of free fatty acid (FFA) and peroxide value (PV). It also aimed to determine the color and odor development changes of oil through quality scoring in sensory evaluation.

1.1. Palm oil

Frying in oil allows high rates of heat transfer into the food making it an excellent heating medium (Singh, n.d). Among oils, palm oil is the most-widely used vegetable oil in the world produced from the pulp of the fruit of the oil palm tree (European Palm Oil Alliance, n.d.). Palm oil is an edible vegetable oil (Njoku et al., 2010).

Palm oil is composed of different fatty acids: unsaturated, polyunsaturated and saturated fatty acids (Henry, 2011). But on average, the amount of saturated fatty acids in palm oil is of almost equal amount with its unsaturated fatty acids content (European Palm Oil Alliance, n.d.).

One of the major advantages of using palm oil is its ability to maintain its characteristics under high temperature. High temperatures could render quality changes and production of unwanted by-products to other oils (European Palm Oil Alliance, n.d.).

1.2. Free fatty acids

One of the most common indexes for quality determined during production of edible oil is the Free Fatty Acid (FFA) content. These are spontaneously generated from oils even during storage and responsible for oil rancidity (ASTM, 1973).

The physical and chemical properties of fats and oils are indicated by fatty acid composition. This is due to the composition of fats and oils which are mainly made up of glycerol and fatty acids (Henry, 2011). Fatty acids can be either saturated or unsaturated. In a saturated fatty acid, the fatty acids are packed tightly enabled by the composition of carbon atoms connected with a single bond. While in unsaturated fatty acids, the structure contains one or more double bonds making it difficult for the fatty acids to pack tightly (European Palm Oil Alliance, n.d.).

Free fatty acid is an indication of the extent of hydrolysis occurring in the oil which cleaves off fatty acids from the ester linkage with the parent triglyceride molecule (Teoh, 2006). The factors influencing the levels of FFA are time, temperature and moisture content upon exposure of oil to storage, processing and heating. Free fatty acids are more prone to oxidation and turning rancid (Mahesar et al., 2014).

Free fatty acid is measured in terms of "Acid Number" or the number of milligrams of potassium hydroxide which neutralizes the alkali reactive groups in one gram of oil (ASTM, 1973).

1.3. Peroxide value

Peroxide value is an indication of quality and stability of oil since it is a measure of the extent of reactions causing rancidity (Ekwu and Nwagu, 2004).

Specifically, it measures the oxidation levels in oil which requires the testing for primary and secondary breakdown product. Peroxide value is one of the most common methods used in measurement of the primary oxidation level. The formation of hydroperoxides is measured by PV determination (Miller, n.d)

1.4. Odor and color development of oil

There are several changes observed upon exposure of oils to repeated frying. This causes oxidative and thermal reactions that alter the physicochemical, nutritional and sensory properties of the oil (Che man and Jasvir, 2000). Moreover, development of sensory characteristics of oil in terms of darkening of color results from the formation of polar compounds (Singh, n.d). The odor, however, is attributed to the fatty acid esters of oils converted into FFA (Anwar et al., 2003). These parameters are included as indicators of poor oil quality (Kheang et al., 2006).

2. Materials and methods

The fish (*Sardinella spp*) samples were freshly obtained from Jasaan Fish port, Misamis Oriental, Philippines. It was directly transported to Northern Mindanao Food Innovation Center, Cagayan de Oro for preparation and vacuum frying.

2.1. Sample preparation

Fish samples were washed. Scales, internal organs, head and tails were removed. The samples were divided into batches of 3kg each allocated for every frying. Ten batches were prepared, five batches randomly selected and subjected to chilling for 12 hours at 5-7°C and the other five batches were directly vacuum fried after fish sample preparation. The fish samples were vacuum fried at 110°C for 30 minutes after every frying oil samples were obtained and subjected to physico-chemical analyses and sensory evaluation.

2.2. Free fatty acid determination

10 grams of palm oil was added with 50mL ethyl alcohol and heated until boiling. The boiled sample

was added with phenolphthalein indicator and titrated with 0.1N NaOH. Titration was done until the sample color changed into light pink.

2.3. Peroxide value determination

5 grams of palm oil was added with 15mL of dichloromethane, 10mL acetic acid and 0.5 potassium iodide. It was allowed to stand for one minute with occasional shaking. 15 mL distilled water and 1 mL of 1% starch solution was added. Titration was done using 0.1N $Na_2S_2O_3$ as titrant until blue color disappears.

2.4. Sensory evaluation

50 panelists from Mindanao University of Science and Technology were asked to score the intensity of quality parameters of the oil in terms of color and odor obtained after each frying. Samples were randomly presented according to the masterlist. Panelists recorded the ratings on the score sheets provided.

2.5. Statistical analysis

One-way ANOVA was used to determine if there is a significant difference in the FFA, PV, color and odor of oil after frying. DNMRT was further implored for comparison of two means.

3. Results and discussion

Edible oils have low FFA content due to the various processes that it has undergone (Tandy, 1984). The free fatty acid values increased as the number of frying increases. The values obtained from the palm oil used until fifth vacuum frying both the fresh fish and chilled fish were still below 0.6mg KOH/g oil, the standard limit of FFA value from Codex Alimentarius (Table 1).

Frying food in heated oil causes the moisture to produce steam. A bubbling action occurs with respect to the evaporation of the water, this gradually subsides as food is fried. Water, steam and oxygen are the main initiators of the chemical reactions in the frying oil and food. These attack the ester linkages of triacylglycerol which then produces di- and mono- acylglycerols, glycerol, and free fatty acids. Free fatty acid content increases as the number of frying is increased (Chung, 2004).

Similar increasing trend was observed in the study of Diop (2014). Acid value increase after frying fish was of larger range as compared to frying meat and potatoes. The moisture content of the fried products hastens the acceleration of the hydrolysis of oil. Increase of the FFA could be attributed to the water which promotes hydrolysis of triacylglycerols into glycerol and free fatty acids (Velasco et al., 2008). The instability of FFA content can be attributed to the vapour pressure at frying temperature which causes it to evaporate from the surface occurring at the same time that it is produced (Abd El-Rahman et al., 2006).

Table 1: Average free fatty acid values of palm oil used in vacuum frying fresh and pre-chilled Tamban (*Sardinella spp*)

Number of Frying	Free Fatty Acid (g KOH/g Oil)	
	Fresh Fish	Pre-Chilled Fish
Initial	0.09	0.09
1st	0.14	0.17
2nd	0.18	0.22
3rd	0.22	0.23
4th	0.22	0.29
5th	0.26	0.31

The primary oxidation of oil is caused by lipid oxidation which results to peroxide formation. Under normal conditions, oils initially form hydroperoxide compounds, an indicator of lipid oxidation (Diop, 2014). Peroxide value is a measure of oxidant or rancidity and the color darker is also effect from oxidation (Wannahari, 2012).

Heating causes the oil to undergo reactions like oxidation, hydrolysis and polymerization (Choe, 2007). Repeated heating of oil causes elevation of the peroxide values in the frying oil (Jaarin, 2012). Table 2 shows the same trend of result for peroxide values of the palm oil used.

For oil used in vacuum frying the fresh Tamban (Sardinella spp), peroxide value was within the Codex Alimentarius standard of 10 meq/kg for until third frying only. On the other hand, the peroxide values of palm oil using in vacuum frying pre-chilled fish was still within the standards until fifth frying (Table 2).

Table 2: Average peroxide value of palm oil used in vacuum frying fresh and pre-chilled Tamban (*Sardinella spp*)

Number of Frying	Peroxide Value (meq/Kg)	
	Fresh Fish	Pre-Chilled Fish
Initial	2.0	2.0
1st	5.16	5.16
2nd	7.73	6.44
3rd	8.38	7.09
4th	10.31	7.09
5th	18.70	9.62

Table 3 presents the results in quality scoring for the evaluation of odor. Increasing mean scores indicate increase of notable odor of the oil sample. Subjecting to ANOVA, there is a significant difference in the data for the palm oil used in vacuum frying fresh and pre-chilled fish at 5% level of significance. For palm oil used in vacuum frying fresh fish, DNMRT shows a difference in oil samples from 1st and 2nd frying. Further, there is a difference on the odor of 2nd and 3rd, and 3rd and 4th frying for the palm oil used in vacuum frying pre-chilled fish.

The chemical reactions occurring in oil during heating produces volatile and non-volatile compounds. During frying, the volatile compounds evaporate in the atmosphere along with the steam while the non-volatile compounds are sources of flavour and quality changes of oil (Choe, 2007). Futhermore, off-flavor which makes oil to be less acceptable is attributed to the free fatty acids and the oxidized compounds developed. The hydrolysis is further accelerated by di- and mono- acylglycerols, glycerol, and free fatty acids (Frega, 1999).

Table 3: Mean sensory scores of odor evaluation of palm oil used in vacuum frying fresh and pre-chilled Tamban (*Sardinella spp*)

Number of Frying	Mean Scores	
	Fresh Fish	Pre-Chilled Fish
1st	2.14	1.74
2nd	2.70	2.04
3rd	3.02	3.04
4th	3.50	3.88
5th	3.62	4.30

Table 4 presents the results in quality scoring for the evaluation of oil color. An increase in the mean score indicates an intensified brown color of the samples. Subjecting to ANOVA and DNMRT at 5% level, there is a significant difference in the data for palm oil used in vacuum frying fresh fish during 3rd and 4th frying. Further, for the color of palm oil used in vacuum frying pre-chilled fish, DNMRT shows that there is a difference on oil used in 2nd and 3rd frying, and 3rd and 4th frying.

Reusing of cooking oil promotes degradation both chemically and physically. Chemical reactions occurring enhance foaming, darkening of oil color, increased viscosity and off-flavor (Leong, 2015).

Table 4: Mean sensory scores of color evaluation of palm oil used in vacuum frying fresh and pre-chilled Tamban (*Sardinella spp*)

Number of Frying	Mean Scores	
	Fresh Fish	Pre-Chilled Fish
1st	1.88	1.62
2nd	2.42	1.90
3rd	2.68	3.02
4th	3.72	3.86
5th	4.30	4.60

Result of sensory evaluation in terms of the color of the oil was supported by the results of color determination using pantone. A subjective evaluation system was done which matched the color of the oil to the pantone color matching system. There was an observed increase in the intensity of color as the number of frying increases. From Table 5, as the number of frying of oil was increased, the pantone values with respective color composition increases and the color also intensifies. The observed data is under the yellowish to golden brown range.

Pantone reveals an increase in the intensity of color of the oil for the first to third frying for fresh fish and pre-chilled fish. The increasing trend in color is consistent with the sensory evaluation, although results in sensory evaluation for oil used in frying fresh fish detected a significant difference on the oil used after 4th and 5th frying while pantone color is constant. Moreover, significant difference for color evaluation was also observed in 1st and 2nd frying oil for pre-chilled fish. This is also consistent with the pantone color composition results as seen in Table 7.

Table 5: Pantone values of the color of palm oil used in vacuum frying fresh and pre-chilled Tamban (Sardinella spp).

Number of Frying	Mean Scores	
	Fresh Fish	Pre-Chilled Fish
1st	7751	7758
2nd	7752	7751
3rd	7753	7753
4th	7753	7753
5th	7753	7753

Table 6 presents the color composition of pantone results for the color evaluation of the oil used in frying fresh fish. The colors yellow, orange and black are increasing while the color white is decreasing. This implies that the oil has increasing color intensity as it reached fifth frying.

Table 6: Color composition of pantone values of oil used in frying fresh Tamban (Sardinella spp).

Fresh Fish Pantone Values	Color Composition			
	Pantone Yellow 012	Pantone Orange 021	Pantone Black	Pantone Trans White
7751	17.81	1.51	2.55	78.13
7752	26.46	2.67	2.28	68.59
7753	28.96	4.10	3.74	63.20
7753	28.96	4.10	3.74	63.20
7753	28.96	4.10	3.74	63.20

Figs. 1, 2 and 3 show the actual color of oil after first to fifth frying. The color intensifies from first to third frying and remained constant until fifth frying. The range falls under yellowish to golden brownish color.

Fig. 1: Color of oil after first frying of fresh fish.

Fig. 2: Color of oil after second frying of fresh fish.

Fig. 3: Color of oil after third to fifth frying of fresh fish.

Similar trend was observed in the color composition of pantone results for the oil used in frying pre-chilled fish. However, large difference in color was observed in the oil used after first and second frying. The oil used after the first frying was more of yellow and white, while the oil used after second to fifth frying has a combination of orange in its composition. This confirms the significant difference observed in the sensory evaluation of oil used after first and second frying.

Table 7: Color composition of pantone values of oil used in frying Pre-Chilled Tamban (Sardinella spp).

Fresh Fish Pantone Values	Color Composition			
	Pantone Yellow 012	Pantone Orange 021	Pantone Black	Pantone Trans White
7758	36.10	-	1.72	62.18
7751	17.81	1.51	2.55	78.13
7753	28.96	4.10	3.74	63.20
7753	28.96	4.10	3.74	63.20
7753	28.96	4.10	3.74	63.20

Figs. 4, 5 and 6 are the actual color of the oil after frying pre-chilled fish. It was observed that after the first and second frying, of pre-chilled fish, the oil was lighter as compared to the oil used after first and second frying of fresh fish. However, similar color was obtained after the third frying of both fresh and pre-chilled fish.

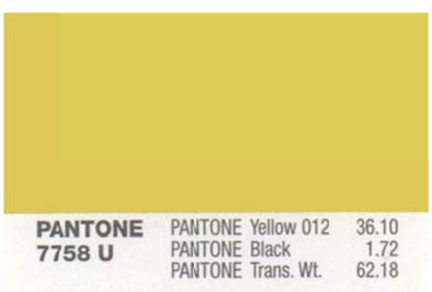

Fig. 4: Color of oil after first frying of pre-chilled fish.

Fig. 5: Color of oil after second frying of pre-chilled fish.

Fig. 6: Color of oil after third to fifth frying of pre-chilled fish

4. Conclusion

The following conclusions can be drawn from the study: (1) there is a gradual increase in the FFA values and PV of palm oil used on vacuum frying fresh and pre-chilled Tamban (*Sardinella spp.*). The Free fatty acids (FFA) of both fresh and pre-chilled tamban (*Sardinella spp.*) were within the range of acceptable value. Moreover, subjecting the fish to chilling prior to vacuum frying prevents rapid increase of peroxide value and stays within range until fifth frying as compared to the peroxide value of oil used in frying fresh fish which was within acceptable value until third frying only. (2) The intensity of color and odor increases with increased number of frying the palm oil was subjected.

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