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(Research Article)



# Analysis of the effect of time and heat on free fatty acid levels in dura and tenera palm oil

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## Abstract

Palm oil is one of the most extensively used edible oils in the world due to its low cost relative to other edible oils. Free fatty acids in palm oil are a key feature linked to its quality and commercial value. Palm oils which have high free fatty acids content are poor in quality and suffer significant losses during the refining process and also affect consumer's health. Free fatty acids in palm oil were determined by titration method with a preferable index showing the comparison among Zomi palm oil, Abepa palm oil and Agric palm oil with three different storage times after production. The free fatty acid contents by prolonged heating of the palm oils at a standard temperature were determined. Different time ranges in five trials of heating of the samples of palm oil were performed. High free fatty acid content was observed with longer storage and heating. The Zomi palm oil had the highest free acid content while the Agric palm oil had the lowest free fatty acid content after four minutes of heating.

**Keywords:** Free fatty acid; Zomi palm oil; Agric palm oil; Abepa palm oil; Titration

## 1. Introduction

Palm oil has become highly popular and widely consumed due to its relatively lower cost compared to other edible oils. Palm oil can be derived from the mesocarp (flesh) and the kernel (seed). Ripe palm fruits tend to yield a larger quantity of oil from the mesocarp compared to unripe ones [1-3]. Similar to other fats, palm oil consists of fatty acids that are esterified with glycerol [4-5]. Elevated levels of free fatty acids in palm oil not only diminish its quality but also present health hazards, including the risk of hypertension for consumers [6-8]. The amount of free fatty acids (FFA) in palm oil is influenced by the time between production and consumption. Throughout the stages of storage, processing, and heating, the oils and fats in palm oil are subjected to various environmental factors. Due to their inherent instability, free fatty acids are more susceptible to oxidation and the development of rancidity [9-11]. Free fatty acids present in oil are prone to autoxidation and can act as pro-oxidants in edible oils. As a result, the level of free fatty acids is a crucial characteristic associated with the quality and economic value of palm oils.

Heat treatment is applied to the harvested palm fruit mesocarp, but even before this treatment, lipase activity can lead to significant oil losses and necessitate expensive measures to control the quality of free fatty acids. During the extraction and processing of palm oil, there is a significant formation of high levels of free fatty acids. The extraction of crude palm oil (CPO) involves subjecting the oil to elevated temperatures, typically ranging from 90 to 140 °C. At ambient temperature, the extracted crude palm oil contains carotenes, which are subsequently discarded. The hydrolysis of fatty acids during the extraction process is the primary mechanism responsible for the production of free fatty acids in palm oil [12-17]. In addition, free fatty acids occur naturally in crude palm oil and can be generated through various processes. Enzymes present in palm fruits, microbial lipases, and the reaction between oil and water during storage can all contribute to the production of free fatty acids [12, 18-19]. The palm fruits themselves contain active lipase enzymes that hydrolyze the palm oil, leading to the formation of free fatty acids. Furthermore, damaged palm

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fruits and prolonged storage can contribute to increased levels of free fatty acids, thereby impacting the quality of palm oil [20-22].

A high concentration of free fatty acids in palm oil can result in an unpleasant fermented-like odour. The presence of moisture during heating or frying can lead to the formation of free fatty acids, resulting in the rapid development of distinctive flavours and aromas. However, in the context of oils, fats, and food products, these flavours are generally regarded as defects [23-25]. Oils with high levels of free fatty acids undergo substantial losses during the refining process. Conversely, crude palm oil with low free fatty acid content exhibits favourable physicochemical properties and can be valuable for various industrial applications [26-29].

Palm oil has emerged as a primary cooking oil in several countries worldwide, such as Malaysia, Indonesia, Papua New Guinea, Nigeria, and Ghana [30-32]. In Ghana, the Western Region is known for its favourable conditions for palm tree cultivation, making it a significant producer of palm oil. The two main types of palm fruits cultivated in Ghana are the dura palm fruit and the tenera palm fruit. The tenera palm fruit, characterized by its thick mesocarp, shorter cultivation period, and high yield, is particularly prevalent [33-37]. Local and small-scale farmers predominantly cultivate and harvest dura palm fruits, whereas industrial firms primarily rely on tenera palm fruits. In Takoradi, the region's capital, market women and hawkers offer various types of palm oil, including Zomi palm oil, Abepa palm oil, and Agric palm oil, to consumers. These palm oil products are sourced from local farmers, as well as self-made palm oil and the regional oil industries. Zomi palm oil is derived from a blend of dura and tenera palm fruits, while Abepa palm oil is exclusively produced from dura palm fruits, and Agric palm oil is obtained from tenera palm fruits. Palm oils sourced from local farmers and self-made producers are typically available in smaller quantities, and therefore, the assessment of the free fatty acid levels is ignored. The market women selling palm oil at the Takoradi Market in the Western Region of Ghana may lack awareness of the biochemical processes that contribute to the contamination of the palm oil they sell and the potential health effects on consumers. It is important to note that most of the palm oil sold at the market has already undergone processing and decanting into bottles before being sold. Hence, the objective of the study is to examine the levels of free fatty acids in the palm oil available at the Takoradi Market. This analysis aims to provide insights into the quality of the palm oil being sold. By understanding the quality of the palm oil, the study aims to raise awareness among market women and consumers about the importance of ensuring the safety and purity of the palm oil they buy and consume.

## 2. Materials and Methods

### 2.1. Materials

Ethanol (96%), Sodium hydroxide (NaOH) (69.7%), Phenolphthalein, Zomi palm oil (30% dura/70% tenera), Abepa palm oil (100% dura), Agric palm oil (100% tenera)

### 2.2. Sampling

The purposive sampling method was used to collect the required samples [38-41]. Three types of palm oils were selected for the analysis. These three include Zomi palm oil, Abepa palm oil and Agric palm oil. Nine bottled samples of palm oils were collected. Three of the samples were Zomi palm oil, three were Abepa palm oil and the other three were Agric palm oil. Each of the three groups of oil samples was collected according to days one, day six and day nine storage after production. Each of the nine palm oil samples was taken from nine different market women at the central market in Takoradi, the Western Region of Ghana. The Zomi palm oil and Abepa palm oil samples of palm were obtained by the market women with the oils sourced from small-scale oil producers while the three Agric samples were obtained by the market women with the oil sourced from Benso Oil Palm Plantation Ltd (BOPP Ltd) at Tarkwa in the Western Region of Ghana.

### 2.3. Experimental Analysis of Zomi and Agric Palm Oil

Samples were labelled as Az, Bz, and Cz to represent Zomi palm oil samples, Ap, Bp, and Cp to represent Abepa palm oil samples and Ag, bg and Cg to represent Agric palm oil samples. Before the titration analysis, a 1.5 L neutral ethanol (96%) solution was prepared by the addition of 0.1 M NaOH and 3 drops of phenolphthalein indicator to reach an equivalent point of pale pink. The purpose of this chemical preparation is to neutralize the ethanol to avoid interferences during titration. Five trial tests were done on each sample. A 10 g sample of palm oil in an Erlenmeyer flask was heated on a hot plate at 250 °C at varying times of 0.5 to 4 min for each trial. A 25 ml of hot neutral ethanol followed by 3 drops of phenolphthalein indicator was added to the hot palm oil samples. The various samples were titrated against 0.1M NaOH to obtain titre values. The free fatty acid (FFA) for each sample was acquired using the formula;

$$\text{FFA} = \frac{Titre\ Value}{Sample\ weight} \text{ x Molecular weight}$$

## 3. Results and Discussion

The results for the Zomi palm oil samples generally show an increase in free fatty acid (FFA) with increasing production dates. A slight increase in FFA was also generally observed with increasing heating time for each sample. Table 1 shows an FFA increasing range from 5.560 % to 7.140 % and titre values ranging from 22.500 ml to 28.800 ml with a heating time increase at 250 °C per 10g of oil.

**Table 1** Free Fatty Acid (FFA) in Zomi Palm Oil at 205 °C

| **Az one day after the production date** | | |
|---|---|---|
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 5.560 | 22.500 |
| 1 min | 5.670 | 23.000 |
| 2 min | 5.710 | 22.800 |
| 3 min | 6.350 | 33.000 |
| 4 min | 6.400 | 33.200 |
| **Bz six days after the production date** | | |
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 6.030 | 24.000 |
| 1 min | 6.040 | 24.100 |
| 2 min | 6.190 | 24.700 |
| 3 min | 6.410 | 26.500 |
| 4 min | 6.620 | 26.700 |
| **Cz nine days after the production date** | | |
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 6.010 | 24.000 |
| 1 min | 6.230 | 24.700 |
| 2 min | 6.250 | 25.000 |
| 3 min | 6.270 | 25.100 |
| 4 min | 7.140 | 28.800 |

Figure 1 shows a gradual increase in FFA level from 0.5 min to 2 min for all the Zomi palm oil samples. A sharp increase of FFA level from 5.710 % to 6.350 % was seen for Az from 2 min to 3 min heating followed by a slight increase in level of 6.400 % at 4 min heating. A study increase of FFA level of 6.040 % to 6.620 % from 1 min to 4 min was observed for Bz while a sharp increase in FFA level of 7.140 % was observed from 3 to 4 min heating time for Cz.

A similar general increasing path of FFA and titre values was also observed for Abepa palm oil as shown in Table 2 which shows a FFA increasing range from 3.530 % to 5.430 % and titre values ranging from 12.200 ml to 14.800 ml with heating time increase at 250 °C per 10g of oil.

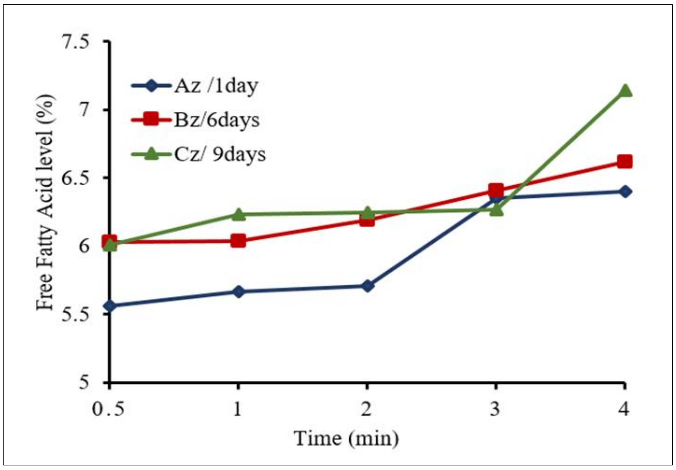


**Figure 1** Assessment of free fatty acid (FFA) level in Zomi palm oil with increasing time (Mass of Az; Bz; Cz = 10g; heating temperature=250 °C)

**Table 2** Free Fatty Acid (FFA) in Abepa Palm Oil at 205 °C

| **Az one day after the production date** | | |
|---|---|---|
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 3.530 | 22.500 |
| 1 min | 4.300 | 23.000 |
| 2 min | 4.330 | 22.800 |
| 3 min | 4.700 | 33.000 |
| 4 min | 4.720 | 33.200 |
| **Bz six days after the production date** | | |
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 4.050 | 24.000 |
| 1 min | 5.020 | 24.100 |
| 2 min | 5.130 | 24.700 |
| 3 min | 5.210 | 26.500 |
| 4 min | 5.430 | 26.700 |
| **Cz nine days after the production date** | | |
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 5.110 | 24.000 |
| 1 min | 5.310 | 24.700 |
| 2 min | 5.330 | 25.000 |
| 3 min | 5.410 | 25.100 |
| 4 min | 5.620 | 28.800 |

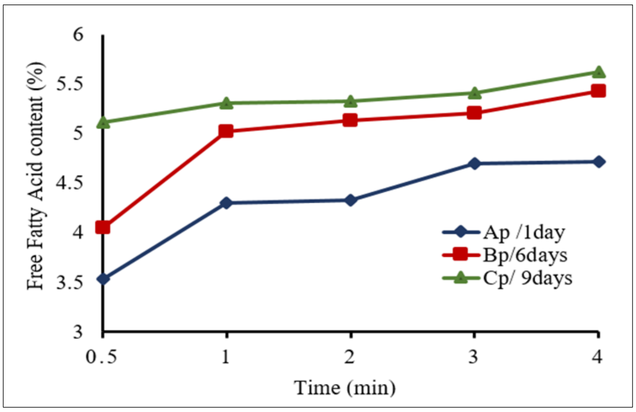


**Figure 2** Assessment of free fatty acid (FFA) level in Abepa palm oil with increasing time (Mass of Ap; Bp; Cp = 10g; heating temperature = 250 °C)

Figure 2 shows a sharp increase in FFA level of 3.530 % to 4.300 % from 0.5 to 1 min heating, a slight increase in FFA level from 1 to 2 min heating, an appreciable increase in FFA level from 2 to 3min heating and a slight increase in FFA level from 3 to 4 min for Ap. A sharp increase of FFA level from 4.050 % to 5.020 % was also seen for Bp from 0.5 to 1 min heating followed by a steady slight increase of FFA level from 1 to 4 min heating. A slight steady increase of FFA level from 5.110 % to 5.620 % from 0.5 min to 4 min heating was observed for Cp.

Agric palm oil similarly showed a general increasing path of FFA and titre values as shown in Table 3 which shows a FFA increasing range from 2.980 %to 3.730 % and titre values ranging from 12.200 ml to 14.800 ml with heating time increase at 250 °C per 10g of oil.

**Table 3** Free Fatty Acid (FFA) in Agric Palm Oil at 205 °C.

| **Ag one day after the production date** | | |
|---|---|---|
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 2.980 | 12.200 |
| 1 min | 3.010 | 12.100 |
| 2 min | 3.280 | 13.100 |
| 3 min | 3.340 | 13.200 |
| 4 min | 3.420 | 13.500 |
| **Bg six days after the production date** | | |
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 3.210 | 12.800 |
| 1 min | 3.250 | 13.000 |
| 2 min | 3.330 | 13.200 |
| 3 min | 3.420 | 13.800 |
| 4 min | 3.460 | 13.900 |
| **Cg nine days after the production date** | | |
| **Time** | **FFA (%)** | **Titre value (ml)** |
| 0.5 min | 3.120 | 12.700 |
| 1 min | 3.380 | 13.800 |
| 2 min | 3.600 | 14.500 |
| 3 min | 3.650 | 14.700 |
| 4 min | 3.730 | 14.800 |

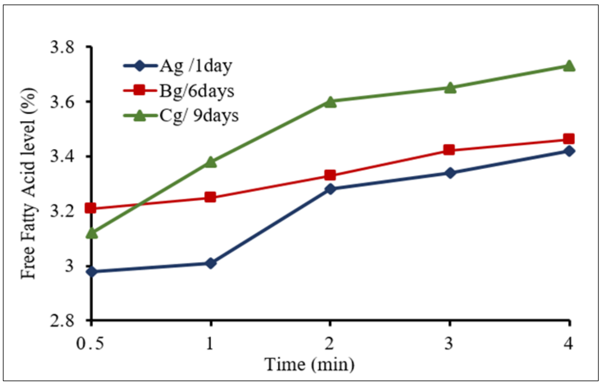


**Figure 3** Assessment of free fatty acid (FFA) level in Zomi palm oil with increasing time (Mass of Ag; Bg; Cg = 10g; heating temperature=250 °C )

Figure 3 shows a sharp increase in FFA level from 3.010 to 3.280 from 1 to 2 min of heating for Ag followed by a study increase of FFA level from 2 min to 4 min. A slight increase of FFA level from 3.210 % to 3.250 % was seen for Bg from 0.5 to 1 min heating followed by a steady increase of FFA level from 1 to 4 min heating. A sharp steady increase of FFA level from 3.120 % to 3.730 % from 0.5 min to 2 min heating was observed for Cg with a lower increase in FFA level from 3 to 4 min heating.

Comparable result of FFA levels for the three groups of samples for the longest storage period after production in Figure 3 shows that the Zomi palm oil sample generally showed about 50% higher FFA level than that of the Agric palm oil. The Abepa palm oil also showed a higher FFA level compared to the Agric palm oil. Analysis of Zomi palm oil sample showed higher FFA level ranging from 5.56 % to 7.17 % which exceeds the preferred index of 5 % [43]. An FFA level of 4.720 % which was within the preferred index was observed for Abepa palm oil sample stored one day after production at 4 min heating while higher FFA levels of 5.430 % and 5.620 % above the preferred index were observed at 4 min heating for the Abepa palm oil samples stored for six and nine days after production. The FFA level of Agric palm oil samples which range from 2.98 % to 3.65 % were within the preferred index. The increase in FFA level for the Zomi palm oil and Abepa palm oil may be due to poor harvesting, storage and production processes. With local farmers, the harvesting of ripening palm fruit is done with no quality control standards which can lead to enzymatic action in damaged ripened palm fruits by microbial lipases during storage. Also, prolonged storage causes palm fruits to react with water through hydrolysis [12, 18-19]. These actions may have increased the FFA content in the Zomi palm oil and the Abepa palm oil samples. Furthermore, the Zomi palm oil and Abepa palm oil are produced by local farmers with no temperature regulation. High oxidation as a result of prolonged heating during the oil extraction process may also result in the formation of FFA through hydrolysis. Improperly kept production equipment by these small-scale farmers may generate molds which could account for defects in flavours, aroma and FFA generation.

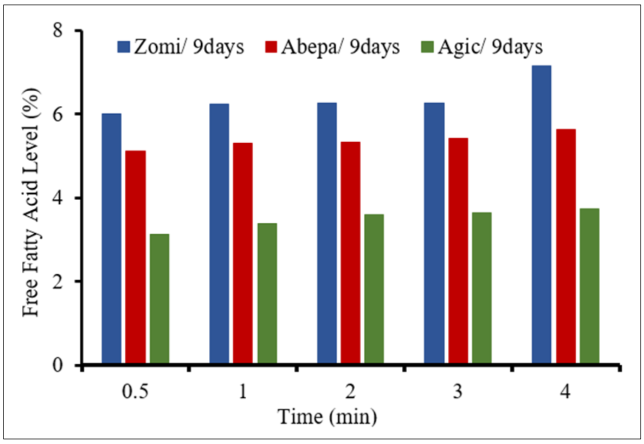


**Figure 4** Comparison of free fatty acid (FFA) levels in Zomi palm oil, Abepa palm oil and Agric palm oil at nine days after production

## 4. Conclusion

The free fatty acid (FFA) content was successfully determined through an acid-base titration procedure. Prolong heating at 250 °C progressively increases the FFA level in all the palm oil samples. The increase in FFA level during prolonged heating was conclusively due to the development of oxidation and hydrolysis action in the various palm oils. The Agric palm oil was observed to possess the preferred free fatty acid level for consumption. This is a result of the quality standard observed during the harvesting, storage and extraction process compared with the production and storage conditions for the Zomi palm oil and Abepa palm oil.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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