

## Changes in Characteristics of Palm Oil During Vacuum and Atmospheric Frying Conditions of Sweet Potato

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### ABSTRACT

The qualities of fried palm oil used under two different sets of frying conditions with sweet potato chips were investigated. The study investigated the effect of vacuum and atmospheric pressure on the total polar compounds (TPC), viscosity, color, acid value and peroxide value of the oil samples. The oil qualities after vacuum frying were studied for 8 h d<sup>-1</sup> for eight consecutive days. The results showed that the TPC reached 12.75%. Viscosity was in the range of 71.13-72.13 cP and the acid value was 0.46 mg KOH/g. The peroxide value gradually increased over the first 4 d and then decreased. The L\* value decreased with longer frying time, while a\* and b\* values increased. The oil qualities of atmospheric frying for 8 h d<sup>-1</sup> for six consecutive days revealed a high percentage of TPC (25.25%); viscosity also increased to 92.35 cP. The acid value was at 1.23 mg KOH/g and the peroxide value increased in the first three days, then decreased. The L\* value decreased, while a\* and b\* values were higher on the first day of frying and leveled off afterward.

**Key words:** acid value, color, frying condition, oil quality, repeated oil, vacuum fry

### INTRODUCTION

Snack foods and especially fried snacks, are a popular form of refreshment among consumers, because frying in oil helps to create a great flavor and texture. Repeated use of oil at high temperature causes quality deterioration through chemical reactions, such as oxidation, hydrolysis and polymerization. The resultant decomposition products adversely affect the flavor and color of the frying oil and the fried products. These reactions damage the oil quality by increasing the amount of free fatty acid and polar compounds that affect consumers' health by causing a higher risk of: cancer, high blood pressure and coronary heart disease. In addition, food producers are also

in danger, as they may sniff oil vapor that can cause lung cancer. (Hein *et al.*, 1998; Goburdhun *et al.*, 2000).

Vacuum frying is a novel technique, where the food is fried at somewhat lower temperature and pressure, which slows the deterioration of the oil compared with atmospheric deep frying. Moreover, products from vacuum frying retain their flavor, which makes them more familiar to the consumer. In addition, the product's color is similar to fresh, natural, raw ingredients. This research aimed to investigate the changes in the chemical and physical qualities of palm oil used to fry repeatedly different samples of sweet potato under vacuum frying and atmospheric deep-fat frying conditions.

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## MATERIALS AND METHODS

### Sample preparation

Sweet potato (*Ipomoea batatas*), with yellow flesh and a diameter size of about 4-6 cm, was purchased locally from the Saphanmai fresh market in Bangkok between November 2007 and February 2008. Each sample was cleaned and peeled. In order to avoid surface browning, the sample was soaked in water before it was cut into thin pieces approximately 1.5 mm thick. The slices were soaked in water again and drained for 20 min before frying.

### Experiment

The same ratio of sweet potato to oil (1:40) was used for both vacuum frying and atmospheric frying.

**Vacuum frying** (Batch vacuum fryer with 10 L oil capacity)

An amount of 175 g of sliced sweet potato was fried in 7 L of palm oil under vacuum pressure conditions of 630 mmHg, at 110°C for 10 min. After frying, the product was centrifuged at 1,000 rpm for 3 min. Frying was undertaken every hour (eight times per day) for eight consecutive days. The same frying conditions were employed for all experiments. About 50 g of oil was collected at the beginning of the experiment and at the end of every working day.

### Atmospheric frying

Three liters of palm oil was heated until the temperature reached 170°C for 30 min before 75 g of prepared sweet potatoes were fried under atmospheric conditions at 170°C for 90 sec every hour (eight times per day) for six consecutive days. A sample of the frying oil was collected at the end of each day after the eighth hour of frying.

### Oil quality measurement

Total polar compounds (TPC) were determined while the frying oil was still warm (about 80°C) using a food-oil monitoring

instrument (Ebro electronic FOM 310, Germany). The color value of the palm oil was measured by a spectrophotometer (Minolta CM-3500d, Japan) and the viscosity was determined using a viscometer at 25±0.5°C (Brookfield DV-III, USA). About 50 g of collected oil sample was kept in a light brown glass bottle and stored at a temperature of -18°C to avoid further chemical changes while waiting for chemical analysis. Determination of the acid (AOAC, 1995) and peroxide (AOAC, 1995) values was performed after each experiment was completed.

### Statistical analysis

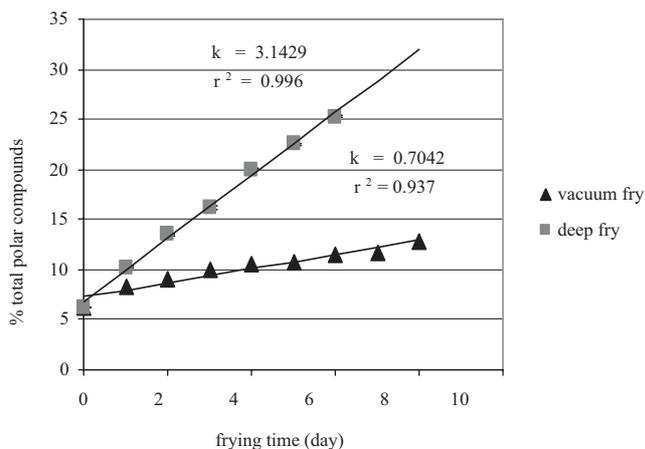
The experiment was conducted with two replications using a randomized complete block design (RCRD).

The results were analyzed using the SPSS for Windows software, version 12.0 (SPSS Inc., Thailand)

## RESULTS AND DISCUSSION

### Total polar compounds (TPC)

It was found that the longer the frying time, the higher the TPC that was observed under both vacuum and atmospheric conditions (Figure 1). The TPC content in fresh oil (day 0) was 6.25%, which increased to 10.25% on day 1 and 25.25% on day 6 under atmospheric frying conditions. Under vacuum frying conditions, the TPC content was 12.75% at day 8. This result showed that the rate of increase in TPC under atmospheric conditions was higher than under vacuum frying conditions because the higher frying temperature accelerated chemical reactions that rapidly deteriorated oil quality. This result conformed to the study of Razali and Badri (2003), which reported that frying frozen French fries under atmospheric conditions at 180°C for 4 min eight times a day for five consecutive days produced frying oil that contained 30% TPC.



**Figure 1** Total polar compounds (TPC) in vacuum frying oil and atmospheric (deep) frying oil.

The kinetic deterioration of oil in terms of the TPC content could be explained by a zero order chemical reaction (Equation 1);

$$C = C_0 + kt \quad (1)$$

where,  $C$  = quality index at time  $t$

$C_0$  = quality index at time 0

$k$  = zero order reaction rate constant (quality unit/time)

$t$  = time of frying (d)

The rate constant ( $k$ ) of frying oil was 0.7042 and 3.1429 TPC%/day, with goodness of fit ( $r^2$ ) values of 0.937 and 0.996 for vacuum and atmospheric frying conditions, respectively. A similar result was observed in cottonseed oil used to fry sliced potatoes at 155-195°C under atmospheric conditions with a rate constant ( $k$ ) value of about 1.4760-1.9710 h<sup>-1</sup> and a correlation coefficient ( $r^2$ ) in the range of 0.9510-0.9910. (Houhoula *et al.*, 2002)

Note that the TPC of the atmospheric frying oil increased to 25.25% on day six, which was higher than the maximum value set by the Thailand Ministry of Public Health (MOPH), according to MOPH Notification No. 283, which claims that the TPC content of commercial frying oil must not exceed 25% to protect consumers' health.

### Viscosity

The initial palm oil viscosity (day 0) was 71.88 cP. The viscosity of frying oil from the beginning until the last day (day 8) under vacuum frying showed no significant change ( $p > 0.05$ ), with values in the range of 71.13 to 72.13 cP. The viscosity of oil used under atmospheric conditions from day 0 to day 6 tended to increase and this result could be explained by the zero order kinetic reaction equation with a kinetic rate constant ( $k$ ) value of 3.6500 cP d<sup>-1</sup> and an  $r^2$  value of 0.9726 (Figure 2). As the viscosity values under vacuum frying conditions were not significantly different, it was not possible to determine the kinetic rate constant. When frying oil is used continuously over a long period, the carbon in the fatty acid molecules (which are elements of triglyceride) causes cross linking of the carbon to form cyclic compounds, dimers, trimers, epoxides and polymers with higher molecular weight, resulting in increased oil viscosity (Shyu *et al.*, 1998).

### Acid value

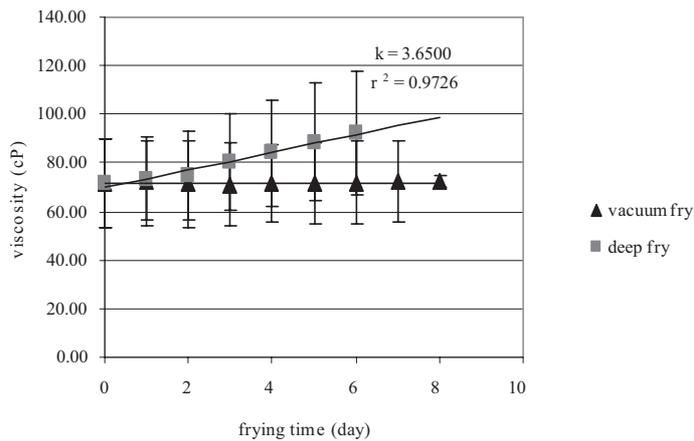
The acid value of the initial oil was about 0.28 mg KOH/g, with a steady increase in the value observed under both sets of frying conditions. Oil used in atmospheric frying had a higher acid value than oil used in vacuum frying,

which was a similar result to that obtained with the TPC values. The zero order kinetic reaction also can be used to explain the result, with a reaction rate constant ( $k$ ) of 0.0222 and 0.1579 mg KOH/g oil  $d^{-1}$  and  $r^2$  values of 0.9591 and 0.9783 under vacuum and atmospheric frying conditions, respectively (Figure 3). Such an acid value indicated that a hydrolysis reaction had occurred between steam and the triglycerides. (O' Brien, 1993).

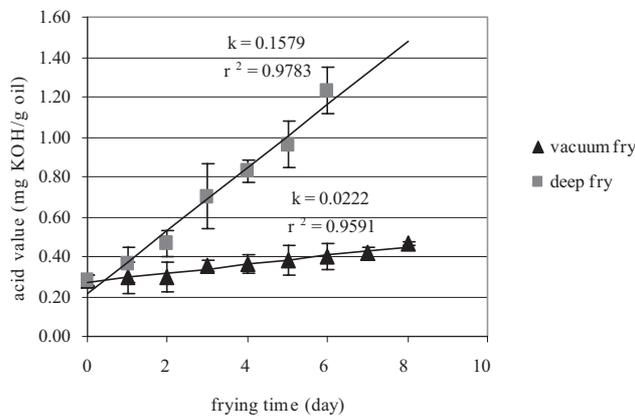
**Peroxide value**

During the period from day 1 to day 4 of the experiment, the peroxide value of the frying oils tended to increase and then level off. After

that, the values decreased slightly under both frying conditions (Figure 4). When the oil was heated, an oxidative reaction occurred producing hydroperoxide, which is a volatile decomposition product (VDP), and the decomposition of hydroperoxide formed aldehydes, ketones, lipoperoxides and free radicals afterward. Since the peroxide value was used to determine the peroxide linkage of the reaction, the decomposition resulted in a lower peroxide value. These chemical compounds resulted in undesired odor and flavor in the oil and its fried product. Similar results were reported by Che Man *et al.* (1999). However, it was not possible to determine a kinetic order reaction in this case.



**Figure 2** Viscosity of vacuum frying oil and atmospheric frying oil.

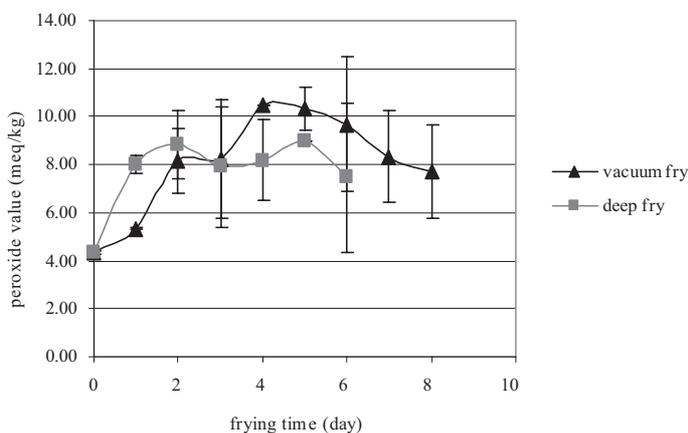


**Figure 3** Acid value of vacuum frying oil and atmospheric frying oil.

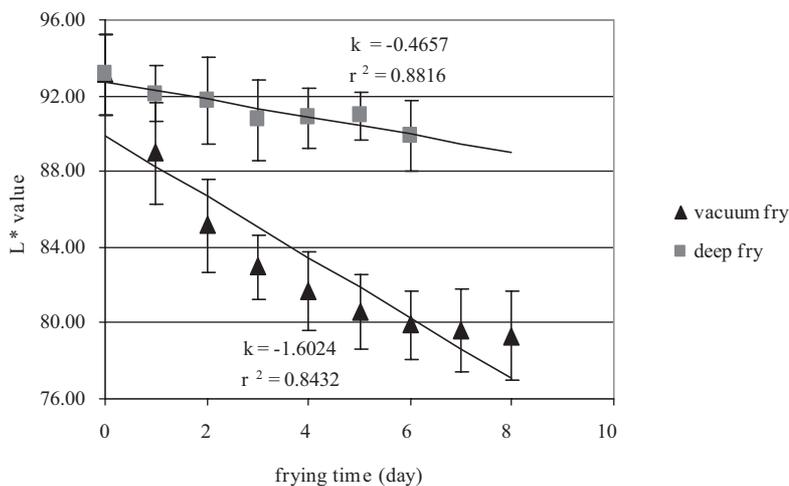
### Color ( $L^*$ , $a^*$ and $b^*$ )

Changes in the color (CIE  $L^*$   $a^*$   $b^*$ ) of the oil are shown in Figures 5 and 6. The  $L^*$  values in Figure 5, show the decreasing trend in both frying conditions. The decrease was the result of chemical reactions in the frying oil, i.e. hydrolysis, oxidation, polymerization and other chemical changes, though the identification of the colored compounds and their mechanism of forming was not clear (Maskan, 2003). However, the lower  $L^*$  values indicated a darker vacuum fry oil was observed although the chemical deterioration index, TPC, acid value and PV (Figures 1, 3 and

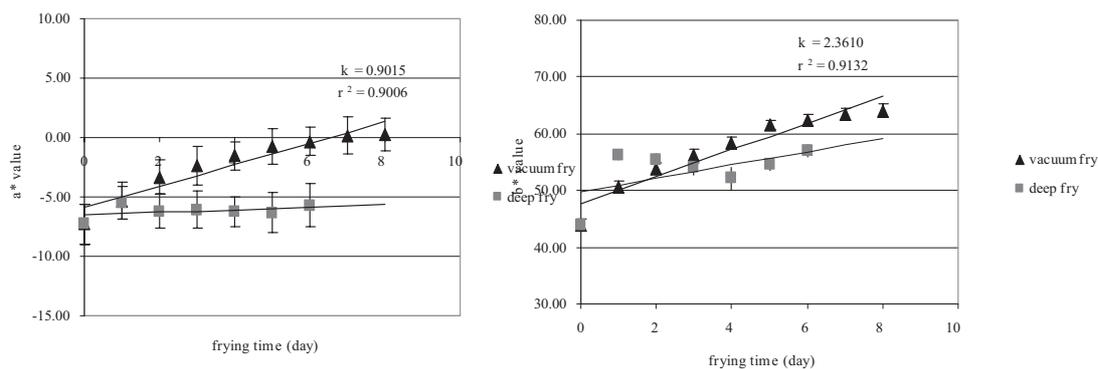
4) had lower values. It was assumed that the vacuum frying time (about 10 min) was long enough to accelerate the Maillard browning reaction, compared with the 1 min 30 sec used in atmospheric frying. This assumption was supported with the increasing values of  $a^*$  in the vacuum frying oil, as shown in Figure 6. The decreasing  $L^*$  value under both vacuum and atmospheric conditions could be best fitted by a zero order reaction with a kinetic rate constant of  $-1.6024$  and  $-0.4657$  unit  $d^{-1}$  and  $r^2$  values of  $0.8432$  and  $0.8816$ , respectively.



**Figure 4** Peroxide value of vacuum frying oil and atmospheric frying oil.



**Figure 5**  $L^*$  value of vacuum frying oil and atmospheric frying oil.



**Figure 6** Graphs of color values for vacuum frying oil and atmospheric frying oil: A) a\* value; and B) b\* value.

Figure 6 shows that the a\* and b\* values of oil used in vacuum frying tended to increase and could be represented by a zero order reaction with a kinetic rate constant value of 0.9015 and 2.361, and an  $r^2$  value of 0.9006 and 0.9132, respectively. In contrast, the a\* and b\* values of oil used under atmospheric conditions increased during the initial day of frying and was then somewhat constant afterward and so was not suited to kinetic reaction modeling to explain the change.

Total polar compounds have been used as a quality index for used oil in this study, since TPC is also used by the Thailand Ministry of Public Health (Ministry of Public Health, 2004). Oil under atmospheric frying conditions could be used for six consecutive days, while oil used under vacuum conditions could be used for more than eight consecutive days. Based on the predictive kinetic model, used palm oil under vacuum conditions could be used for 26 consecutive days, but this prediction requires confirmation by conducting an experiment.

## CONCLUSIONS

Used palm oil under vacuum conditions had a lower rate of increase in total polar compounds, acid value and viscosity compared to used palm oil under atmospheric conditions. The

peroxide value rose at the beginning of the experimental period and then reduced because it became unstable and decomposed. The L\* value decreased with repeated frying of the oil, which contradicted the increase in a\* and b\* values. Based on the acceptable level of total polar compounds notified by the Thailand Ministry of Public Health, palm oil can be used for frying under atmospheric conditions for six consecutive days (48 times). If the frying were carried out under vacuum conditions, used palm oil could be used at least eight consecutive days (64 times).

## ACKNOWLEDGEMENT

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