

CHANGES IN PALM OIL DURING FRYING UNDER ATMOSPHERIC AND VACUUM CONDITION

Leila Nateghi^{1*}, Morvarid Yousefi^{2*}, Zahra Jafarian³ and Mahshid Rezaei⁴

¹Department of Food Science and Technology, Faculty of Agriculture, Varamin-Pishva Branch, Islamic Azad University, Varamin, Iran

²Young Researchers Club, Islamic Azad University, Tehran North Branch, Tehran, Iran

³Tehran Dairy Scientific Applied Training Center, Tehran, Iran

⁴Department of Medicinal Plant, Varamin-Pishva Branch, Islamic Azad University, Varamin, Iran

*Corresponding author e-mail: leylanateghi@yahoo.com

ABSTRACT

The aim of this study was to evaluate the effects of different frying conditions (Atmospheric and vacuum) on some physicochemical properties (color, density, refract index, total polar and polymer compounds, viscosity, acid and peroxide value) of palm oil. As frying progressed, in both conditions free fatty acid, polar and polymer content, viscosity and color properties redness and yellowness increased but this was higher under atmospheric than vacuum frying. Refract index increased in atmospheric condition but will be constant in vacuum frying. Lightness decreased relatively faster under atmospheric than vacuum frying. Generally, vacuum frying is more suitable than atmospheric frying with regards to fewer changes in oil composition and properties. Vacuum frying at 115°C retains the oil quality and longer use of oil compared to atmospheric frying at 180°C.

Key word: Palm oil, vacuum frying, Atmospheric frying.

INTRODUCTION

Frying is affected by many factors, such as oil type, temperature, size and nature of the food product, warm up time and time of frying. During frying many changes occur, such as water evaporation, oil uptake, and gelatinization of starch, denaturation of protein, crust formation and color changes. Heat is transferred from the oil to the food and when boiling point of water is reached, moisture is lost from the product and steam released from food. Due to high temperature (150–200 °C) and the presence of oxygen the oil undergoes a series of physicochemical reactions such as thermal degradation, hydrolysis, oxidation and polymerization and therefore formation of a variety of volatile compounds, monomeric and forward polymeric component. Most of the volatile components are lost during the frying time, whereas, the non-volatile component produced primarily by thermal oxidation and then polymerization of unsaturated fatty acids are accumulated in the oil and in the fried product (Debnath *et al.*, 2012). Thus, the composition of fresh oil is different from that of abused oil (Rossi *et al.*, 2009). These compounds are retained in the oil and cause further decomposition. These substances are absorbed by the fried food, consumption and affect the human health. Decomposition of the oil not only affects the usability of the oil and on the other hand, contributes over time to human health hazards, such as potential gastrointestinal disorders in the human body. Vacuum frying is a suitable method of reducing the temperature, oxygen and therefore reducing oil content in fried product, reducing oil deterioration and maintaining fried food nutritional quality. In vacuum frying process, oil is heated under reduced pressure and temperature causing a reduction in the boiling points of the moisture in the food (Da Silva *et al.*, 2008). It is a method that can be used to produce fried product with the enough degree of dehydration without excessive scorching or darkening of the product with higher retention of their natural organoleptic properties such as flavors and color. In industry use of oil is repeated several times and therefore its changing should be monitored. The aim of this study was the investigation of physicochemical changes in palm oil during repeatedly frying of potato in vacuum and atmospheric condition.

MATERIALS AND METHODS

Material

Palm oil and potato were purchased in the local store in Malaysia. Potato was cleaned, peeled, cut into pieces about 2 mm thick manually and before frying process, soaked in water due to inhibition of browning reaction). All chemicals were purchased from Merck (Darmstadt, Germany).

Methods

Peroxide index ascertained according to AOAC standards NO. 965.33. The present of acidity was done according to National standard No. 4178. Refract index was determined according to national standard NO. 5108. The soapy number was determined according to national standard No. 4888. Iodine number was ascertained according to national standard NO. 5108. Viscosity of sample was determined using a viscometer (25°C) (Brookfield DV-III, USA). Polar and polymer components were measured by the method described by Basuny *et al.* (2013). The color properties were determined by a spectrophotometer (Minolta CM-3500d). In order to determine the amount of fatty acid compounds all experimental samples were methylated according to AOAC standard No. 969.33 and then in order to examination of fatty acid compound Gas chromatography (GC) were used. It was used GC Model, Youglin 6000 equipped with a flame ionization detector (FID). The detector temperature was set at 280 °C. Compounds were separated on (60 m, 0.25 mm, 0.2 µm) capillary column. The carrier gas was hydrogen at a flow rate of 1 mL/min. Injection temperature was 250°C, program temperature was 155°C, for 5 minutes and increasing of temperature (10 °C in per minute) until 180 °C and keeping it for 30 minutes.

Frying

Frying process was employed according to Kusucharid *et al.*, (2009). Sliced potato was fried under atmospheric conditions at 180°C 90 sec and under vacuum conditions at 110°C (630 mmHg) for 10 min. Frying was down every hour (eight times per day) for ten days. About 20 g of oil was collected at the end of every working day.

Data Analysis

Data collected from the aforementioned study samples were analyzed based on 0.05% coefficient of error. The data analysis was performed using MINITAB statistical software, release 14.2 (MINITAB Inc., state college, PA and USA).

RESULTS AND DISCUSSION

Physicochemical properties of fresh palm oil included color properties, acid value, peroxide value, viscosity, polymer and polar content, and refract index in oil as shown in Table1. In fresh oil acidity and peroxide value was 0.41 mg KOH/g and 0.91 meq/kg, respectively. It means that the hydrolysis and oxidative degradation of oil was very low and so polar content was sleeve (4.02 %), also its free of polymer and therefore viscosity was low (73.71(cP)).The color of oxidative product is dark and if its substance formed the color of oil will be darker. Color properties in cloud L*, b*, a* in fresh oil was 97.53, 38.39 and -2.15. All of this data has shown that palm oil was fresh, safe and suitable for frying. Also the level of acidity, peroxide, refract index was in acceptable limit of codex standard (Codex standard:210, 1999). Analyzed changes of physicochemical properties of palm oil during frying in both atmospheric and vacuum condition, include refract index, peroxide value, acidity, viscosity, polymer and polar compounds, are presented in Table 2 and 3. First day of atmosphere and vacuum condition peroxide was 1.22 and 1.21 meq/kg and in 7th day reached to maximum level (11.62 and 13.54 meq/kg) and finally decreased and reached to 9.03 and 7.82 meq/kg respectively. Yaghmur *et al.* (2001) have shown that peroxide value of argan oil after 26.5 h frying sharply increased. This result conformed to the study of Serjouie *et al.* (2010), which reported that during natural frying of canola oil at the first, hydroperoxide content was increased and reached to 10.53 and then decreased. Also, Yousefi and Nateghi (2012) observed this behavior for canola oil and reported that this changing was more sever in atmosphere than vacuum condition. During atmospheric frying, acid value statistically significant increased from 0.61 % in first day to 2.01% in tenth day of process ($p \leq 0.05$) but during vacuum condition acidity from first day (0.41 %) increased insignificantly and reached to 0.62 % in tenth day ($p \leq 0.05$). In vacuum condition, due to low pressure water of system changed to vapor and removed so its effect on hydrolysis will be decreased. So in vacuum frying acidity of oil was very lower than atmospheric condition. This result conformed to the study of Yousefi and Nateghi (2012) who investigated the changing of canola oil and reported that during natural frying acidity increased more than vacuum frying. Yaghmur *et al.* (2001), investigated the changing in argan oil during 26.5 h frying, who reported that acidity from 20.8 % reached to 30.2%. Also similar result was observed by Kusucharid *et al.* (2009) who reported during usual deep frying acidity of palm oil from about 0.2 % increased and reached to about 1.5 % and vacuum condition decreased this value. There are no certain standard to determine the fry-life of frying oil. It is a usual commercial practice to remove frying oil when the level of free fatty acid reaches 1.0 % (Bansal *et al.*, 2010). Therefore in both condition in all the frying time, the oil was suitable in view of the free fatty acid. Polar substance in fresh oil includes free fatty acids, tocopherols, sterols, mono and diglycerides, and other oil-soluble components. Polar content in fresh palm oil was 4.02%. During frying, oils suffer different reaction like as hydrolysis and oxidation to produce polar component, such as, alcohols aldehydes, ketones, acids, mono and

diglycerides. In both condition total polar content increased significantly ($P \leq 0.05$) as the frying period increased. The total polar components in atmosphere and vacuum frying were 4.82 % and 4.11 % in first day and reached to 33.75 and 10.23 % in tenth day of frying, respectively. This result revealed that the rate of increase in polar content under vacuum conditions was lower than atmospheric frying. This sharp changing of this factor refers to high temperature which accelerated chemical reactions and therefore rapidly changed the oil. In both condition of frying, viscosity of oil was increased but, this different from first day to last day of frying period in atmosphere condition was significant ($P \leq 0.05$) while in vacuum condition was almost similar. It means, in atmosphere and vacuum condition, viscosity in first day was (73.82cP and 75.74 cP) and in tenth day reached to (74.23cP and 109.31 cP) respectively. This data was matched with Kusucharid *et al.*, (2009), Yousefi and Nateghi (2012) that confirm during vacuum frying of palm and canola oil viscosity will be constant, but in atmosphere condition viscosity will be increased. Serjouie *et al.* (2010) has shown that viscosity of canola oil from 59.88 cP reached to 84.10 cP in atmosphere condition. Refract index of oil increased during frying time (Table 1, 2). This index in fresh oil was 1.455 and statistically significant increased and reach to 1.456in atmosphere frying. ($P \leq 0.05$) but in vacuum condition significantly will be constant. It means transparency of oil decrease that refers to formation of different component. According to codex standard acceptable limit for refract index is 1.454- 1.456, therefore in vacuum condition in all the time of frying refract index was acceptable but in atmosphere condition only up to 4 day was in acceptable limit. Serjouie *et al.* (2010) reported similar result.

Table 1. Properties of fresh canola and palm oil.

a*	b*	L*	Viscosity (cP)	Acid value (Mg KOH/g)	Peroxide value (meq/kg)	Polar Content (%)	Polymer Content (%)	Refractive index
-2.15 ± 0.06	38.39 ± 1.22	97.53 ± 0.72	73.71 ± 1.22	0.41 ± 0.03	0.91 ± 0.01	4.02 ± 0.02	0.0 ± 0.00	1.455 ± 0.10

L*: Lightness; b*: Yellowness; a*: Redness

Table 2. Properties of palm oil during frying under atmospheric condition.

Time (day)	Peroxide value (meq/kg)	Acid value (mg KOH/g)	Polar content (%)	Viscosity (cP)	Polymer content (%)	Refractive index
1	1.22 ± 0.13 ^a	0.61 ± 0.01 ^a	4.82 ± 0.11 ^a	75.74 ± 0.15 ^a	0.91 ± 0.04 ^a	1.455 ± 0.00 ^a
2	2.91 ± 0.19 ^a	0.79 ± 0.03 ^a	6.93 ± 1.04 ^b	77.27 ± 0.13 ^a	1.31 ± 0.16 ^a	1.455 ± 0.01 ^a
3	5.94 ± 1.12 ^b	0.91 ± 0.02 ^a	9.73 ± 0.18 ^c	79.06 ± 0.22 ^b	2.74 ± 0.35 ^b	1.459 ± 0.00 ^a
4	7.63 ± 1.01 ^b	1.13 ± 0.03 ^{ab}	11.38 ± 1.37 ^d	84.52 ± 1.01 ^c	4.17 ± 0.64 ^c	1.461 ± 0.02 ^a
5	9.31 ± 1.12 ^c	1.28 ± 0.05 ^{ab}	15.90 ± 0.84 ^e	89.73 ± 0.63 ^d	6.28 ± 0.51 ^d	1.468 ± 0.02 ^a
6	10.84 ± 0.93 ^c	1.40 ± 0.02 ^b	20.03 ± 3.51 ^f	93.43 ± 0.11 ^e	7.12 ± 2.63 ^{de}	1.473 ± 0.03 ^{ab}
7	11.62 ± 1.13 ^c	1.52 ± 0.01 ^b	24.81 ± 5.17 ^g	97.61 ± 1.07 ^f	8.19 ± 1.80 ^e	1.473 ± 0.01 ^b
8	9.62 ± 1.40 ^c	1.64 ± 0.03 ^b	28.02 ± 1.32 ^h	101.22 ± 0.17 ^g	9.01 ± 2.11 ^e	1.475 ± 0.03 ^b
9	10.45 ± 1.36 ^c	1.77 ± 0.04 ^b	31.67 ± 3.74 ⁱ	104.92 ± 1.08 ^h	9.81 ± 1.26 ^{ef}	1.476 ± 0.01 ^b
10	9.03 ± 1.07 ^c	1.83 ± 0.01 ^b	33.75 ± 2.31 ^j	109.31 ± 0.14 ⁱ	10.13 ± 1.09 ^f	1.479 ± 0.04 ^b

^{a-i}: significant difference within column at confidence level of $p \leq 0.05$.

Color properties

Changes in the color of palm oil in both atmosphere and vacuum condition during process are shown in Table 4. It was observed that the color properties of oil increased with frying time period. There have been several point on thermal color degradation of oil that include: formation of FFA by hydrolysis of triglyceride, particle of fried foodstuff that remain to surface of pan that lead to over processing and degraded to smaller particle as coloring component, reaction of amino- carbonyl, that is the main way for no enzymatic browning, and phospholipids were another agent for browning reaction. Different reaction include oxidation, hydrolysis and polymerization, affected

the color of oil and so its color will be darker. Therefore in both frying conditions the lightness (L^*) statistically significant decreased this decrease was sharper in atmosphere frying than vacuum condition ($P \leq 0.05$). L^* values of fresh oil was 97.53 and decreased to reach 68.67 in atmosphere and 92.84 in vacuum frying. Redness (a^*) and yellowness (b^*) values for fresh oil was -2.15 and 38.39 and during frying shows increasing trend. In atmosphere condition a^* and b^* increased significantly and reached to 5.12 and 69.03. This increasing trend observed in vacuum frying but very slower than atmosphere condition. It means a^* and b^* in first day was -1.67 and 38.22 and reach to 1.13 and 58.37 in vacuums frying, respectively.

Table 3. Properties of palm oil during frying in vacuum condition.

Time (day)	Peroxide value (meq/kg)	Acid value (mg KOH/g)	Polar content (%)	Viscosity (cP)	Polymer Content (%)	Refractive index
1	1.21 ± 0.11 ^a	0.41 ± 0.02 ^a	4.11 ± 0.03 ^a	73.82 ± 0.12 ^a	0.11 ± 0.03 ^a	1.455 ± 0.01 ^a
2	2.95 ± 0.32 ^a	0.43 ± 0.01 ^a	4.93 ± 0.12 ^a	73.22 ± 0.15 ^a	0.98 ± 0.03 ^{ab}	1.455 ± 0.02 ^a
3	4.12 ± 0.73 ^b	0.49 ± 0.06 ^a	5.38 ± 0.17 ^a	73.56 ± 0.09 ^a	1.42 ± 0.03 ^b	1.455 ± 0.00 ^a
4	7.88 ± 0.52 ^c	0.53 ± 0.10 ^a	6.12 ± 0.35 ^{ab}	73.94 ± 0.25 ^a	2.17 ± 0.03 ^c	1.455 ± 0.01 ^a
5	9.02 ± 1.13 ^c	0.54 ± 0.02 ^a	7.30 ± 1.01 ^b	74.38 ± 0.42 ^a	2.94 ± 0.03 ^c	1.455 ± 0.03 ^a
6	11.03 ± 1.06 ^{cd}	0.57 ± 0.04 ^a	8.11 ± 0.92 ^{bc}	74.82 ± 0.10 ^a	3.84 ± 0.03 ^d	1.456 ± 0.00 ^a
7	13.54 ± 1.33 ^d	0.60 ± 0.01 ^a	8.93 ± 0.11 ^{bc}	74.84 ± 0.17 ^a	4.01 ± 0.03 ^{de}	1.456 ± 0.02 ^a
8	9.93 ± 1.09 ^c	0.61 ± 0.05 ^a	9.41 ± 0.02 ^c	74.97 ± 0.08 ^a	4.89 ± 0.03 ^e	1.456 ± 0.02 ^a
9	8.11 ± 2.04 ^c	0.63 ± 0.03 ^a	9.96 ± 0.02 ^c	74.17 ± 0.19 ^a	5.12 ± 0.03 ^e	1.456 ± 0.03 ^a
10	7.82 ± 1.63 ^c	0.62 ± 0.04 ^a	10.23 ± 0.02 ^c	74.23 ± 0.32 ^a	5.45 ± 0.03 ^e	1.456 ± 0.00 ^a

^{a-e}: significant difference within column at confidence level of $p \leq 0.05$.

Table 4. Color properties of palm oil during frying in vacuum and atmospheric condition.

Time (day)	L^*		b^*		a^*	
	Atmospheric	Vacuum	Atmospheric	Vacuum	Atmospheric	Vacuum
1	96.38 ± 1.04 ^a	97.21 ± 0.13 ^a	39.21 ± 1.81 ^a	38.22 ± 0.28 ^a	-1.73 ± 0.03 ^a	-1.67 ± 0.01 ^a
2	94.53 ± 1.17 ^{ab}	97.13 ± 1.37 ^a	41.93 ± 1.04 ^a	39.57 ± 0.92 ^a	-0.69 ± 0.01 ^a	-1.42 ± 0.03 ^a
3	91.94 ± 0.72 ^b	96.83 ± 2.06 ^a	45.62 ± 0.27 ^b	41.38 ± 1.43 ^{ab}	1.28 ± 0.10 ^{ab}	-1.30 ± 0.01 ^a
4	87.31 ± 0.28 ^{bc}	96.74 ± 0.82 ^a	48.72 ± 1.09 ^b	44.02 ± 2.09 ^b	1.96 ± 0.04 ^b	-1.06 ± 0.04 ^a
5	84.04 ± 1.36 ^{cd}	95.87 ± 1.58 ^{ab}	51.53 ± 2.14 ^{bc}	47.21 ± 1.93 ^b	2.68 ± 0.12 ^b	0.18 ± 0.02 ^{ab}
6	80.93 ± 2.07 ^d	95.03 ± 0.42 ^{ab}	54.01 ± 0.92 ^c	50.03 ± 0.17 ^{cb}	3.31 ± 0.04 ^c	0.33 ± 0.01 ^b
7	77.40 ± 0.71 ^d	94.39 ± 1.41 ^b	57.73 ± 0.78 ^c	52.94 ± 1.17 ^c	3.97 ± 0.52 ^c	0.59 ± 0.02 ^b
8	73.84 ± 1.09 ^e	93.85 ± 3.10 ^b	62.16 ± 1.80 ^d	54.61 ± 0.89 ^{cd}	4.22 ± 0.28 ^{cd}	0.76 ± 0.08 ^b
9	71.67 ± 3.10 ^{ef}	93.23 ± 1.90 ^b	64.72 ± 1.03 ^d	56.12 ± 2.71 ^d	4.85 ± 1.06 ^d	0.97 ± 0.04 ^b
10	68.67 ± 0.38 ^f	92.84 ± 0.32 ^b	69.03 ± 0.32 ^e	58.37 ± 0.84 ^d	5.12 ± 0.08 ^d	1.13 ± 0.06 ^b

L^* : Lightness; b^* : Yellowness; a^* : Redness

a-f: significant difference within column at confidence level of $p \leq 0.05$.

Conclusion

In vacuum frying, due to the lower oxygen content and temperature during the process, different reaction such as oxidation, hydrolysis and polymerization was occur less than atmospheric condition. Vacuum frying technology has different advantages that include: has less adverse effects on frying oil quality, has less harmful effect on human's body, can retain natural and fresh flavors and color of the final product. According to this result vacuum frying at 115°C retain the oil quality and longer usage of oil in compare to atmospheric frying at 180°C.

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