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Thermoxidative and Hydrolytic Changes in Oils Used for Frying the Frozen Prefried Foods

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PALM olein with 22.9 h of stability at 100 C and low acid and peroxide values of 0.184% and 1.33 meq/kg, respectively was used to study the deteriorative effect of frying the frozen prefried potatoes and chicken and compared it with the effect of frying the fresh same foods. Quality characteristics of palm olein were monitored by following the development in physical and chemical properties; FH, SmP, RI, Vis, AV, PV, %Pol., %OFA, TBA, Conjugated acids (absorbance at 232 nm, for conjugated diene and at 268 nm for conjugated triene) with the progress in frying hours untill 20 h. Results revealed that frying the frozen prefried foods express more deteriorative effect than the fresh foods throughout the frying prosses.

Keywords: Frying, Frozen prefried potatoes and chicken, Palm olein.

Consumption of frozen foods has greatly increased during the last decades. This development has promoted the growth of new industries, and frozen foods are now commonly used by fast-food restaurants, catering services, and consumers.

Deep fat frying is widely used in food preparation because it provides appealing characteristics. Frying is a process of heat and material transfer where oil is both a heating medium and an enhancer of flavor. As a consequence fried foods are considered a significant part of the diet (Romero, *et al.* 1998, 2000a,b ; Bastida and Sanchez-Muniz, 2002).

The increase level of consumer awareness towards fat composition and its impact on human health could have an effect on selection of fats in the snack food industry. In addition, the choice of frying oil should also be made according to its performance in the frying process (Romero, *et al.* 1998, 2000a).

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A number of physical and chemical changes involving a complex pattern of thermolytic and oxidative reactions occur in fats and oils during deep-fat frying. Under commercial deep-fat frying operations, fat is continuously exposed to air and light for extended periods at temperatures approaching 180°C. The composition of food systems cooked by deep-fat frying will promote chemical changes within the frying oil. These reactions result in significant changes in fatty acid composition and cause a rapid deteioration of the frying oil (Irawandi, *et al.* 2000a).

Lipid oxidation is one of the major deteriorative reactions in frying oils and fried foods, and often results in a significant loss of quality. It is well established that lipid oxidation leads to changes in functional, sensory, and nutritive values as well as in the safety of fried foods (Irawandi, *et al.* 2000b; Abidi and Warner 2001).

Their was a degradation compounds formed due to frying conditions and these compounds have negative effects on the quality of the fried food (Lamboni, *et al.* 1998; xu 1999, 2000 ; xu, *et al.* 2000; Abdel Rahmen 2001; Gertz and kochhar 2001a,b; Houhoula *et al.* 2002). Some of these compounds may also be harmful to human health and play a role in various diseases, as the role of oxidation in the initiating events of coronary heart disease (Marsic, *et al.* 1992; Katan, *et al.* 1995; Eder and Stangl 2000). This thermal degradation should be studied not only for technological reasons (production of fried foods with acceptable qualities) but also for safety and nutrition because it is now known that some polar compounds from frying fats can present a certain toxicity (Cuesta, *et al* 1993; Romero, *et al* 1998, 2000b).

Oxidative stability of frying oil can be improved by using fats with low unsaturation, but their high saturated fatty acid content makes them less desirable from a nutritional standpoint (Arroyo, *et al* 1995).

For this reason, consumption of monoenoic fats has increased throughout the world. Nutritional advantages of oleic acid have been recognized in recent years (Gupta 1993; Nestel, *et al.* 1994; Samah 2001; Samah and Fyka 2002).

The properties that make palm oil so suitable for frying is fatty acids composition as mentioned by Berger (1989) and it's mainly virtual absence of linolenic acid, the moderate content of linoleic acid and the relatively high content of the most stable acids, oleic and saturated fatty acids.

Palm olein is a popular deep-frying oil in fast food outlets due to its oxidative stability (47% saturates, 40% oleic, 11% polyunsaturates) and good flavor stability and good taste (Allam 1994; Xu, *et al.* 1999a,b , 2000).

This study was conducted to investigate the effect of frying frozen prefried potatoes and chicken on the frying performance of the palm oil by monitoring the changes in physicochemical properties of the frying oil compared with frying the same fresh foods.

Material and Methods

Materials

Refined, bleached, and deodorized palm olein (RBD-PO) was obtained from Misr Gulf Oil Processing Company, Cairo, Egypt.

Quick frozen straight cut potatoes (Grade A) and quick frozen chicken prefried in RBD-PO by the manufacturer for 1 min before quick freezing, were used in the frying tests. These frozen foods were selected to be fried in palm olein oil because they are the frequently used in deep-fat frying by the fast food, take-away restaurants and consumers.

Potatoes purchased locally were washed, peeled, straight cut by the cutting machine into uniform potatoes fingers and washed with water and submerged in water until needed. Chicken purchased locally were washed, cut into uniform pieces and submerged in water until needed.

Frying procedure and oil sampling

Fresh and frozen prefried potatoes and chicken were fried in 1.5 L of RBD-palm olein using a domestic thermoelectric fryer with a temperature control. The thermostat was set at 190°C and the actual measured temperature inside oil was 180°±5° C. Heating time required to bring the oil to 180 C before introduction of food was ~ 15 min.

Frozen prefried foods were fried for 3 to 8 min in 100 g batches every 15 min. Fresh potatoes were fried for 5 min in oil at a rate of 100 g every 15 min. Fresh chicken were fried for 8 to 10 min in 100 g batches every 15 min.

Frying foods were carried out when oils temperature reached 180°C and continued untill the 5 hours of frying were period perday, and oils were not topped up during the entire 20 hours of frying (5h/4 days). Samples of frying oils were taken after the daily frying operation and kept at –20° C untill further analysis.

Determination of the susceptibility to oxidation with the rancimat method

Five grams of oil sample was accurately weighed into each of the six reaction vessels, and the following procedure was carried out according to the method described by Tsakins, *et al.* (1999). The Metrohm Rancimat 679 was switched on until the temperature of the oil batch reached 100 C. Then 60 ml of distilled water was placed into each of the six conductivity cells, and the air flow was set at 20L/hr. The temperature was checked to ensure that it stayed constant. The air supply was connected to the tubes containing the oil samples, and the chart recorded was started. The determination continued automatically until the conductivity reached the maximum value and the induction period was recorded.

Determination of the physical and chemical characteristics

Refractive index at 25C, smoke point, acid value, peroxide value, and oxidized fatty acids were determined according to the AOCS (1998) methods.

Determination of foam height

The method of Fritsch, *et al.* (1979) was used for the determination of the foam height of the abused oil as follows: Every day a 100 ml glass beaker (4.7cm id) was filled with 40 ml of oil sample taken from the fryer and heated. The initial height of oil was recorded. Potatoes were cut with a machine cutter to obtain similar size cubes (1x1x1 cm3). Five potato pieces were drooped into the beaker when the oil temperature reached 180 C. The maximum foam height in cm was observed and measured.

Determination of the changes in viscosity during frying

Changes in viscosity of oils during frying were determined using Brookfield Viscometer RVDV-1+C/P (Cone/Plate Viscometer, CP-41) connected with water bath Brookfield TC500. Viscosity was carried out at 25±0.01° C according to the method described by Howard (1991).

Determination of conjugated diene and triene

Conjugated diene and triene were identified and determined in oils which were used in frying processes according to the method described by IUPAC (1992) using UV-Vis spectrophotometer Model Labomed, Inc. U.S.A at 232 nm and 268 nm for conjugated diene and triene, respectively.

Determination of polymer compounds content

The method of Pel-Fen and Nawar (1986), was used to determine the percentage of polymer compounds content.

Determination of the thiobarbituric acid value (TBA)

The method of Sidwell, *et al.* (1954) was followed to determine the TBA values.

Results and Discussion

Deep-fat frying is a popular food preparation procedure. In providing an effective medium for energy transfer (Orthoefer, *et al.* 1996) and frying oil also imparts desirable flavor and textural properties to food. Extensive use of oil, however, leads to the release of free fatty acids, oxidative volatiles, and polymers by hydrolysis, oxidative and thermal reactions, respectively. Upon generation of degradative surfactants and volatile chemical, foaming and smoking of the oil ensue, respectively. In addition, uptake of undesirable flavors and excess absorption of oil by the product also occurs (Holownia, *et al* 2000).

Physicochemical characteristics of palm olein

The initial physicochemical characteristics of fresh palm olein used in this study are given in Table (1). The fresh oil was of good quality, as evidenced by its initial low PV of 1.33 meq/kg and an acid value of 0.184% (as oleic acid).

TABLE 1. Physical and chemical properties of palm olein* .

Properties	Results
Refractive Index at 25 C (RI)	1.4718
Smoke Point C (SmP)	250
Foam Height (cm) (FH)	--
Viscosity (cp) at 25 C (Vis)	56.7
Acid Value (AV)	0.184
Peroxide Value (meq/kg oil) (PV)	1.33
Oxidized Fatty Acids % (OFA)	0.09
Polymer Content % (Pol)	0.68
Thiobarbituric Acid (TBA) (absorbance at 530 nm)	0.040
Conjugated Acids	
Diene (absorbance at 232nm) (Ab)	1.09
Triene (absorbance at 268nm) (Ab)	0.365
Stability (h)**	22.9

* Results were mean of duplicate determinations.

** Stability at 100 C was conducted using the Rancimat method

The fresh oil employed in this study was in accordance with the Malaysian palm olein standard (Tan and Oh 1981; Sakata, *et al* 1985).

The oxidative stability of palm olein

The ability of palm olein (PO) to resist the thermal and oxidative degradation at 100 C was measured using the Rancimat method and results are shown in Table (1). PO had an induction period of 22.9 h.

Changes of oil during repeated frying

During frying there was a change in the temperature of the oil (data not shown) during these frozen food fryings was higher (about 10 C during the whole process) than when fresh potatoes and chicken parts were fried. This could be attributed to the differences between the initial temperature for the two materials (frozen and fresh) before frying, suggesting a more damaging temperature (Romero, *et al* 1998). Table (2 and 3) show the quality changes of palm olein throughout the 20 h of frying fresh and frozen prefried potatoes and chicken. During 20 h of frying, all quality parameters of palm olein decreased. The relative changes in peroxide value (PV), acid value (AV), polymer content% (Poly%), viscosity, oxidized fatty acids (OFA), smoke point (SP), foam height (FH), conjugated acids, TBA values, and refractive index (RI) all provided good indices of lipid deterioration rate of the abused oils.

Results in Tables (2 and 3) in general show the deteriorative effect of the frying process, however, in terms of frozen prefried potatoes and chicken the rate of deterioration was faster (more) than fried fresh potatoes and chicken.

TABLE 2. Changes in physical properties of oils during frying period*.

Physical Properties		Potatoes				Chicken			
		Fresh		Prefried		Fresh		Prefried	
Frying hours	0h	10 h	20 h	10 h	20 h	10 h	20 h	10 h	20 h
RI**	1.4723	1.4723	1.4731	1.4732	1.4741	1.4728	1.4732	1.4728	1.4740
Vis. (cp)	56.7	69.0	90.0	72.0	189.0	78.0	92.0	65.5	133.0
SP.(°C)	250	240	232	240	225	240	230	232	220
FH.(cm)	--	--	1.0	0.2	2.0	--	1.2	0.3	1.8

* Results were mean of duplicate determinations.
** Aberviations are shown in Table (1)

TABLE 3. Changes in chemical properties of oils during frying period* .

Chemical Properties		Potatoes				Chicken			
		Fresh		Prefried		Fresh		Prefried	
Frying hours	**0h**	**10 h**	**20 h**	**10 h**	**20 h**	**10 h**	**20 h**	**10 h**	**20 h**
AV**	0.184	0.566	1.070	0.868	1.329	0.790	1.286	0.983	1.835
PV	1.330	3.160	5.280	4.190	14.290	3.000	5.290	3.800	11.810
TBA	0.040	0.108	0.200	0.238	0.279	0.180	0.235	0.216	0.292
%Pol	0.680	1.020	2.030	1.920	7.860	1.300	2.900	2.100	5.800
Ab232nm	1.090	1.221	1.320	1.234	1.278	1.292	1.449	1.274	1.476
Ab268nm	0.365	0.618	1.065	0.701	1.709	0.805	1.302	0.799	1.318
OFA	0.090	0.250	0.580	0.540	0.900	0.380	0.700	0.600	1.100

* Results were mean of duplicate determinations
** Aberviations are shown in Table (1)

The changes in quality parameters of palm olein during frying were also reported by several other workers; Berger (1984); Sakata, et al (1985); Allam (1994); Arroyo, *et al* (1995); Gonzalez-Munoz, *et al* (1996); CheMan and Liu (1999); Irwandi, *et al* (2000a,b); Xu, *et al* (2000).

Changes in physical properties of used oils during frying

Refractive Index (RI)

Refractive index increased during frying period due to the increment in the formation of high molecular weight compounds (Allam 1994). RI of the oils used for frying fresh and frozen foods were measured and results are shown in Table (2). Results showed that RI increased with the increment in frying hours. Results also showed that frying the frozen prefried materials (potatoes and chicken) accelerated the deteriorative effect of frying process more than the deteriorative effect of frying the same fresh materials, respectively.

Viscosity (cp) at 25 ̊C

The viscosity values of oils during frying are presented in Table (2). Palm olein (PO) had an intial viscosity of 56.7 cp at day 0 and increased to 69.0, 78.0; 72.0, 65.5 cp after 10 h of frying fresh potatoes and chicken and frozen prefried potatoes and chicken, respectively and reach 90.0, 92.0; 189.0, 133.0 cp at day 4 (after 20 h of frying the same materials, respectively).

There was a gradual increase in the viscosity of the abused oils used for frying all materials till 10 h of frying. After that, frying frozen prefried potatoes and chicken doubled the viscosity of oils (133.0 cp) and even more (189.0 cp) till the end of frying period (20 h), respectively.

Similarly, Berger (1984) reported that the rate of oxidation of unsaturated fatty acids in palm olein was directly related to the increase in oil viscosity.

Increased in viscosity during frying as a result of the formation of viscous and high molecular weight (polymeric) compounds was also reported by Allam (1994), Abidi and Warner (2001) and Samah and Fyka (2002).

Smoke point (SmP)

In frying, smoke point is used to predict fat stability as a general indicator of fat condition. The amount of smoke emanating from a fryer, is directly proportional to the concentration of low molecular weight decomposition products in the fat. The increase in free fatty acids (acid value) cause a considerable decrease in smoke point of oils (Allam 1994, Samah and Fayka (2002). Results from Table (2) show that smoke point of oils used for frying frozen prefried potatoes and chicken decreased more rapidly than those used for frying fresh foods.

Foam height (FH)

Under frying conditions, both thermal and oxidative polymerization of the oil may take place. Polymers cause foaming when moist foods are deep fried (Allam 1994, Orthoefer, *et al.* 1996, Samah and Fyka 2002). The foam height in cm was measured in oils used for frying fresh and frozen prefried foods and the results revealed that foaming started to appear after 10 h frying the frozen prefried foods (0.2, 0.3 cm when frying the prefried potatoes and chicken, respectively) and continued to increase with the developing of frying hours untill it reached 2.0 and 1.8 cm for the same oils, respectively). While it take 20 h of frying fresh potatoes and chicken to start foaming that were measured 1.0 and 1.2 cm, respectively. These increments in foam height were accompanied by the increase in polymer content and viscosity of abused oils as shown in Table (2 and 3).

Increased foam height with the progress of frying time was also observed by Galal, *et al.* (1992); Allam, *et al.* (1994) and Samah and Fyka (2002).

Changes in chemical properties of used oils during frying

acid value (AV)

The changes in AV (% of free fatty acids) of the oils during frying are shown in Table 3. In this study, there was a marked increase in AV on the first 10 h of frying followed by a gradual increase through the last 10 h of frying .

The increase in the FFA content could be caused by the increased rate of triacylglycerol hydrolysis when water was introduced into the frying system from the fried products.

For all fried samples the length of frying influenced the AV. Frying procedure using palm olein (PO) start with AV of 0.184 (as oleic acid). At day 4 (after 20 h of frying), the AV of oils used for frying fresh potatoes and chicken reached 1.07 and 1.30, respectively, whereas for frying frozen prefried potatoes and chicken reached 1.33 and 1.84, respectively.

From results in Table (3) we could noticed that the alteration rate concerning AV was higher in frying frozen prefried foods (Sakata, *et al.* 1985; Pozo-Diez, *et al.* 1995; Romero, et al 1998, 2000a).

McSavage and Trevisan (2001) reported that during prolonged heating and in the presence of food moisture, hydrolysis of oil occure and ester linkages are broken to yield free fatty acids (FFA). As the FFA concentration increases the smoke point and flash point of the oil decrease, producing a significant fire risk. However, for safety reasons, the temperature of the frying agent should be kept below its smoke point (Samah and Fyka 2002).

Peroxide Value (PV)

PV is a measure of the amount of peroxides formed in fats and oils through autoxidation and oxidation processes. Indirectly, this value indicates the degree of initial oxidation of fats and oils. At day 0 the PV for the fresh palm olein oil before frying was 1.33 meq/kg oil. On frying frozen prefried potatoes and chicken it increased to 14.29 and 11.81 meq/kg oil, respectively, and to 5.28 and 5.29 meq/kg oil on frying fresh potatoes and cicken, respectively, after after 20 h of frying (Table 3). It is also clear from results that frying the prefried foods results in oils with higher PV than those resulting from frying the fresh foods.

The low peroxides values of the oils during frying arise because peroxides tend to decompose at 180°C to form secondary oxidation products (Samah anf Fyka 2002). The possibility of peroxide formation during the cooling period between the intermittent frying and between sampling of the hot oil executing of the peroxide test cannot be discounted. The PV measured here however, do correlate with the greater loss of stability in oils used for intermittent frying. The increase of PV during frying was also reported by Marquez-Ruiz, *et al* (1996, 1999) and Romero, *et al* (1995a, 1998, 2000a).

Thiobarbituric acid (TBA)

From results in Table (3) one can observe that TBA values (as obsorbance at 530 nm) increased rapidly during frying of all samples.

The formation of aldehyde compounds, resulting from decomposition of oil components, which react with TBA reagent producing color measured at 530 nm increased and so TBA values increased with the increase in frying time as an indication for the deteriorative effect of frying process and this was more pronounced with oils used for frying the frozen prefried samples.

Polymer content % (Pol)

Polymeric materials is formed as a result of oxidative and thermal reactions. Results of polymer content analysis of the oils during frying revealed that both duration of frying and the kind of food fried used in this study had influence on the oil degradation products (Table 3). The polymer content of fresh palm olein at day 0 was 0.68%. There was almost a gradual increase in polymer formation through the frying process with the development of frying time in all samples. After the final day of frying (20 h), the polymer content of the oils used for frying fresh potatoes and chicken reached 2.03 and 2.9%, respectively, whereas the frozen prefried potatoes and chicken reached 7.86 and 5.8%, respectively .

The increase in polymer content during frying occurred because the longer the frying time, the greater the amount of decomposition products which would lead to polymer formation (Che-Man and Liu 1999). Free radicals from hydrolysis of hydroperoxides, for example, can react to form polymer and other complex products (Samah and Fyka 2002).

Results in Table (3) revealed that different kind of food being fried, e.g. fresh and frozen prefried either potatoes or chicken have different effect on oil deterioration through frying processess. This effect shown with the more derteriorative effect of frying frozen foods. Rate of alteration was faster when frying frozen foods than the fresh foods.

Abidi and Warner (2001) reported that, elevated levels of high molecular weight polymeric compounds were correlated with the extent of frying oil degradation to serve as indicators for frying oil stability.

Conjugated acids

The abosorbance at 232 nm which also measures the degree of primary oxidation shows a trend of increasing diene content with progress in heating and frying times. It is now generally accepted that theraml polymerization requires the presence of a conjugated double bond in one of the fatty acid (Irwandi, *et al*. 2000a). The results obtained in this study (Table 3) were closely related to the PV. Meanwhile, the longer the frying time, the higher the absorbances at 268 nm of oils and these was indication for the formation of conjugated triene during the 20 h of frying. The trend in 268 nm values of abused oils was similar to that seen with TBA (absorbanes at 530 nm) which also measures secondary oxidative products in oils. Although the absorbance at 268 nm measures particularly the diethylenic ketones, ketones are not monitored in the TBA test (Irwandi, *et al.* 2000b).

These results agree with those previously reported when frozen foods were fried with both sunflower oil and high oleic sunflower oil (Romero, *et al.* 1995a,b, 1998, 1999).

Irwandi, *et al.* (2000a) reported that, there was a trend of increasing diene content with the increase in frying days.

The increse in the formation of conjugated fatty acids in oils used for frying was also reported by Tyagi and Vasishtha (1996); Houhoula, *et al.* (2002); Samah and Fyka (2002).

Oxidized fatty acids% (OFA)

The development in OFA was measured during frying process for all samples either fresh or frozen and results are shown in Table (3). Frying oil deterioration was observed through evolution of thermal oxidized compounds. Oils used for frying frozen potatoes and chicken showed more accelerated degradation than oils used for frying fresh potatoes and chicken. Oxidized fatty acids content (OFA) was increased during the frying period. The increment rate of OFA content formation followed almost the same trend in all frying samples. Results in Table (3) revealed that, there was a sudden rise in OFA formation during the first 10 h of frying all samples and this increment was accompained with the sudden rise of peroxides formation and free fatty acids formation .

Similar results concerning the deteriorative effect of frying the prefried materials compared with the effect of frying the same products as a fresh materials were also observed by several authors; Sebedio, et al (1990) reported that, after 21 fryings of frozen prefried potatoes in peanut oil and in soybean oil, they found 27.5 and 26.8% (wt%) of polar components, respectively. Also, Perez-Camino, *et al.* (1991) found an increase in polar content in oils used six times to fry frozen prefried potatoes and battered hake.

Romero, *et al.* (1998) compared between their results concerning the ratio between the thermoxidative-to-hydrolytic compounds which increased during frying frozen potatoes and the results of others (Romero, et al 1995a,b) results of the comparison concluded that frying frozen potatoes has a greater deteriorative effect than frying fresh sliced potatoes.

Recently, Romero, *et al.* (2000a) observed a high amount of diacylglycerols in frozen prefried potatoes. Thus, these compounds increased during frying as a consequence of an exchange between frozen foods and frying oil.

This is of great interest to the deep-fat frying industry because of the necessity of maintaining a good-quality frying medium as long as possible because of the fat absorption by foods stuffs during frying.

The greater degree of oil deterioration occurring during frying may be explained, in part, by the interaction of food components with the oil. It is also likely that water present in the potato chips accelerated the thermal oxidation and hydrolytic cleavage of the oil. Another factor contributing to the increased deterioration in oil quality during frying experiments may be the increase in effective surface area of the oil caused by agitation of the oil during frying. Also, the deteriorative effect of frying the prefried foods concerning the fatty modifications that occur during repeated fryings was attributed not only to thermoxidative alteration but also to interaction between the bath oil and the fat of the food product to be fried (Guillaumin 1988), and the migration of fatty acids from the food products into the bath oil (Romero, *et al* 1998). Thus, the increased levels of palmitic acid throughout the fryings in palm olein may came from the palm oil used to par-fry these potatoes as explained by Romero, *et al* . 1998, how also reported that the fat extracted from frozen prefried potatoes and chicken parts revealed that this food product was prefried with palm oil, because the fatty acid profile resembled the fatty acid pattern of this oil. These results are in agreement with those found by different authors. Pozo-Diez *et al.* (1995) fried frozen prefried potatoes in high oleic sunflower oil, described that about 80% of the fat from the prefried potatoes was found in the bath oil. Previously, Perez-Camino, *et al.* (1991) observed similar results after frying frozen prefried potatoes and battered hake.

Conclusion

Results of this study confirm the higher deteriorating effect of frying frozen (prefried) foods on the oil quality than when frying fresh foods.

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التغيرات الحرارية الاكسيدية التحلليه الحادثه للزيت اثناء تحمير المنتجات نصف المقليه المجمده

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تم استخدام زيت اولين النخيل ذو ثبات اكسيدى ٢٢,٩ ساعه /١٠٠ م وذو حموضه ورقم بيروكسيد منخفضين (٠,١٨٤% ، ١,٣٣ ملليمكافئ/ كجم زيت ، على التوالى) فى دراسة التأثير التدهورى لتحمير البطاطس والفراخ المجمده السابقه التحمير (نصف المقليه) ومقارنتها بتحمير مثيلتها من الاغذيه الطازجه تم متابعه خصائص وصفات لزيت اولين النخيل بمتابعه التطوير الحادث فى الصفات الطبيعيه والكيميائية للزيت خلال عمليه التحمير لمدة ٢٠ ساعه مثل درجة الدخان ، مقدار تكوين الرغوه ، معامل الانكسار، اللزوجه ، ورقم البيروكسيد ، رقم الحموضه ، % المركبات البوليميرية ، % للاحماض الدهنيه المؤكسده ، قيم اختبار حمض الثوباربيوتريك ، الاحماض الدهنيه المتبادله . دلت النتائج ان عملية تحمير الأغذية المجمده النصف مقليه اكثر تأثيرا فى تدهور الزيت عن تحمير مثيلتها من الاغذيه الطازجه خلال عملية التحمير .