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The effect of kind and temperature of oil used in deep frying on the amount of oil uptake

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Abstract

Thermal process of frying is considered one of the thermal processes that its main objective is improving the edible properties of food. Although in the process some nutritional qualitative indicators of food are decreased due to tolerance of high temperatures as well as oil uptake and increase of caloricity value. Oil uptake during deep frying is an adverse event hygienically and economically that any attempt to reduce it would be appreciated. In this research, the effect of oil type, refined sesame oil, frying oil and semi-hydrogenated oil at three temperatures of 150, 170 and 190°C and times of 5, 10, 15 and 20 min on the amount of oil uptake in slices of potato was tested. Based on the results, frying by refined sesame oil for 10 min and at 150°C showed the lowest amount of oil uptake. In addition, the profile of fatty acids of any oil at the beginning and after 20 min in all three test temperatures was identified by gas chromatography that the results showed no significant changes.

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Introduction

The fats and oils are valuable foods that in addition to the power supply, have an important role in the survival of community health and are in the group of essential consumption goods. Deep frying involves immersion of food in edible hot oil at the temperatures above the boiling point of water for a specific time period. Access to stable and high quality of fried products with the appropriate amount of oil is considered by food industry and consumers (Ziaiifar, 2008). Deep frying process causes a low-calorie product with high nutritional value to become a product with high calories and low nutritional value. Frying oil as a conductor of heat and mass has an important role in the fried foods. It also can be effective in food quality in terms of the amount of trans-fatty acids, endurance, nutritionally and edible quality. Oil quality may be affected by the nature of fried food, emulsifiers, rare metals, residual food components, free fatty acids or other ingredients. Furthermore, in frying oil, the chemical and physical reactions during the heating period cause the quality demolition. In the process of frying a series of different chemical reactions such as polymerization and fission, thermal oxidation and hydrolysis occur. All these reactions lead to increase viscosity, darkening and foam formation and to reduce oil smoke point, which continues by increasing the frying time. The rate of these reactions is dependent on the combination of the oil, temperature and frying time, the continuous or intermittent frying time, the type of food being fried and freshness of frying oil (Kita & Lisinska, 2005). Moreiria *et al.*, (1999) studied the parameters of: 1) cooking oil, 2) temperature of frying oil, 3) Size of slices, 4) oil quality on tortilla chips. Based on the results, the amount of oil uptake was affected by the initial moisture content and particle size. High initial moisture content and small particle size increases the final amount of oil uptake. Fried tortilla chips had more uptakes in itself in "used oil" than in "fresh oil". The results showed that only 20% of final oil uptake in tortilla chips surface was during frying and 64% is absorbed during the cooling phase and 36% remains in the tortilla chips surface. Debnath *et al* (2003) studied the process of moisture removal and oil uptake during deep frying of snacks prepared from chickpea flour and starch. The results showed that increasing the temperature from 150 to 200°C increases the mass transfer coefficient of moisture and oil. Drying process before deep frying was also effective in the frying process. The optimal time of preliminary drying and frying was 40 min and 45 seconds that caused a 45% reduction in the oil uptake of fried product, without sacrificing sensory characteristics. The reason of decreasing the oil during the frying process followed by drying was noted the density of material matrix (Porosity decrease) or increasing the amount of solids. In investigating the reduction of oil uptake, Rimac-Brncic *et al* (2003) used three types of oil, i.e. sunflower oil, palm oil and vegetable oil and also blanching in the solutions of water, citric acid and calcium chloride at temperatures of 180°C for 6 min. Among the fried potatoes, potatoes blanched in water had the highest amount of oil and the samples blanched in citric acid solution had little effect in reducing the amount of oil uptake compared with the samples blanched in calcium chloride solution. Kita & Lisinska (2005) used 7 types of vegetable oil including refined oil of sunflower, soybean, olive, palm, rapeseed, semi-hydrogenated rapeseed and a mixture of vegetable oils and temperatures of 150-160-170-180-190°C and times of 12-10-8-6.5-4.5 min to fry the potatoes. The results showed that the type and time of frying affect the texture of potato fried. Also the temperature influences the fat content and texture of the product. Increasing the frying temperature reduces oil uptake and stiffness of fried potatoes. The potatoes fried in canola oil showed a finer texture and less oil uptake than the other samples. The potatoes fried in solid hydrogenated oils had less oil uptake than liquid hydrogenated oil or liquid canola oil. Pedreschi *et al* (2005) examined the distribution of oil in the potato slices during frying and found that almost all of the oil content is absorbed by potatoes in the first few minutes of frying process and oil uptake is a surface phenomenon that often occur when potato is pulled out of fryer, i.e. the cool-down phase. They also stated that blanching increases the amount of oil in the surface of chips and reduces the temperature of frying to achieve the amount of moisture content given to the product. In a study, the effect of preliminary drying on the texture and the amount of blanched potato oil uptake in the frying process was examined and it was found that the temperature of frying and preliminary drying has a significant effect on final texture and the final amount of oil absorbed by the potatoes. At 120°C, the potatoes were crisper and had more oil amount than potatoes fried 180°C. Preliminary drying also reduces the amount of oil uptake and increase the crispiness of the blanched potatoes after the frying process. The results showed that the lowest frying temperature creates the highest crispiness in the fried potato (Pedreschi *et al.*, 2005).In other study, to investigate the effect of oil type and frying temperatures on the amount of oil uptake and texture of fried potato, the oils of sunflower, canola, soybean, olive, palm, peanut, semi-hydrogenated rapeseed oil and a mixture of semi-hydrogenated canola and palm oil were used. The frying temperatures were 150, 170 and 190°C. The results showed that the amount of fat absorbed by the chips depends on the type of oil for frying. The highest amount of oil uptake was in peanut oil with 35.9% and the lowest was in rapeseed oil with 30.6%. As the temperature increases, the chips had less hardness and absorbed less oil. Per 20°C increase in the temperature reduced, on average, 3% of the amount of oil uptake. Also The temperature below 170°C reduced crispiness of potatoes (Kita *et al.*, 2007). Amany *et al* (2012) studied the effects of different frying processes (under vacuum and atmosphere) on the physical and sensory properties of potato chips as well as the quality of frying oil. Sunflower oil was used in this study. The results showed that frying under vacuum in 120°C under pressure of 5.37 kPa leads to the production of potato chips with acceptable quality and also improve the quality of frying oil. The fried potato is one of the most popular products in the world. Meanwhile, an important factor that affects the taste and texture of potatoes is frying process. Hence, in the study the effect of three factors affecting the amount of oil uptake including temperature, time and oil type was studied and optimal conditions for less oil uptake by fried potato were determined.

Materials and methods

Materials

Potatoes

Potato from kind of Aqale and from Ardabil region with the four years seed, the type of potatoes with yellow inside and cultivation period of 9 months was prepared from the market.

Frying oil (CT)

The oila frying oil, Standard No. 4152 was used. This oil contains palm olein, cottonseed oil, soybean oil as well as antioxidant TBHQ with the maximum amount of 120 ppm, citric acid with the maximum amount of 5 ppm, anti-foaming materials with the maximum amount of 3 ppm, oleic acid, 30.5-31.5 g, linoleic acid 36-37 g and linolenic acid with the maximum amount of 2 percent.

Semi-hydrogenated oil (BT)

Oila semi-hydrogenated oil with the weight of 4500 g with standard number of 2392. This oil contains palm olein oil, soybean oil or sunflower oil or rapeseed oil, beta-carotene color, an antioxidant TBHQ and butter essence. Its linolenic acid content was maximum 5 g, the linoleic acid was minimum 10 g, total of trans fatty acids was maximum 5 g, total of saturated fatty acids was maximum 30 g, antioxidants was maximum 0.012% and beta-carotene color was 0.0005 percent.

Refined sesame oil (AT)

Frying sesame oil of Saman Company with standard No. 1752 was used. The oil is refined and odorless and also has less than 15% saturated fatty acid that contains palmitic acid and stearic acid more. More than 85% of its total fatty acids are unsaturated. Oleic and linoleic acids form more than 80% of the total fatty acids of sesame oil. The percent of oleic acid of sesame oil is about 45% and its linoleic acid is about 40% of the total fatty acids of sesame oil.

Soxhlet apparatus

Soxhlet apparatus used in this study was with Arminad brand made in Iran.

Chromatography device

To determine the profile of fatty acids in the oils used in this study, gas Chromatography device 7890 Agilent equipped with Capillary Column 88 HP and helium gas 99/999 and speed of 1 ml/min was used as gas carrier. In this method, at first, the fatty acids (forming fat) convert to the corresponding methyl esters in order to make their volatile form, and then the resulting solution was injected into the system.

Fryer

The Moulinex brand, 20ADR model, 3-liter volume, automated and with a capacity of 2.1 kg of fries was used. This fryer had the temperatures of 140-150-170 and 190°C and was equipped with an elevator.

Scales

A digital scale, model of AND JAPAN with a capacity of 20 to 2000 g was used.

Slicer machine

Electric slicer machine, Myson brand, model of Mandoline slicer MVS-25 V 7 made in China with 7 blades.

Methods

First, the potatoes were washed and peeled and cut into slices of 1× 0.8 cm by slicer machine. Then, potato slices were washed with distilled water for 30 seconds to remove surface starch. After 30 seconds, the excess water was removed from the potato slices by shaking and putting in absorbent paper. Then, in each experiment, the fryer was filled with the desired oil (sesame oil, semi-hydrogenated oil and frying oil) with the amount of 1.5 liters and reached to the experiment temperature (150, 170, 190°C). The potato slices were poured into the fryer when the desired temperature was obtained and were fried for 20 min. During the frying process, to evaluate the process of increasing the oil uptake during frying and compare the changes in the process in different oil samples, per 5 min, 10 g of fried potatoes are taken out and placed on the metal mesh to lose excess oil for 5 min. Finally, when the potatoes are cooled and reaches to ambient temperature, the amount of oil absorbed in them was determined by Soxhlet apparatus. Also, after the completion of frying, the GC (gas chromatography) was used to observe the changes in the fatty acid profiles.

Statistical analysis

As mentioned, the variables used in this study included three levels of temperature, oil type at three levels and time at four levels. To conduct the research a factorial experiment in a completely randomized design with three replications was used and the mean comparison was performed by Duncan's multiple range test using SPSS software, version 16 at probability level of α=%5.

Results and discussion

The results of oil uptake

According to Table 1 there is no sufficient evidence for accepting the null hypothesis (equality of mean of response variable at all operating levels) (P-value<0.05). So, we can analyzes which at least one level among all the main factors and interactions having P-value<0.05 can have a significant effect on the response variable.

Table 1. Variance analysis of factors affecting oil uptake.

Sources	ds	SS	MS	F
Temperature	2	88.679	44.339	15.22
Time	3	568.318	189.439	65.02
Oil type	2	293.665	119.832	61.13
temperature * time	6	304.009	50.668	17.39
Oil type* time*temperature	4	179.920	44.980	15.44
Oil type* time	6	371.494	61.916	21.25
Oil type* time*temperature	12	202.829	16.902	5.80
Error	65	189.382	2.914	

Table 2. Mean comparison of the effect of temperature on oil uptake.

Treatment(°C)	190	170	150
Mean	9.457 a	9.1a	7.54b

According to Table 2, the difference between the 170 and 190°C is not significant, but there is a significant difference between these two levels and 150°C. In fact, the oil uptake at 150°C is lower than 170 and 190°C significantly.

According to Table 3, there is no significant difference between 5 and 20 min, and both have the highest oil uptake. Then, time of 15 min show high uptake and finally at the time of 10 minutes the lowest oil uptake was observed.

Table 3. Mean comparison of the effect of time on oil uptake.

Time (min)	5	20	15	10
Mean	11.12a	10.99a	7.17b	5.85c

Table 4. Mean comparison of the effect of oil type on oil uptake.

Oil type	AT	BT	CT
Mean	11.03a	7.94b	6.87c

According to table 4, all three types of oil show a significant difference in terms of the amount of oil uptake and the sesame oil, and semi-hydrogenated oil and frying oil have the lowest uptake, respectively.

According to Figure 2, the highest amount of oil uptake was observed at 5 and 20 min, and the lowest amount of oil uptake was observed at 10 and 15 min. Also, regardless of the oil type, the temperature of 190°C, at the time of 10 min had the least amount of oil uptake.

Table 5. Analysis of variance of factors affecting the amount of changes in the fatty acids in frying oil.

Name of fatty acid	Df	SS	MS	P-value
Caproic acid	1	0.10083	0.10083	0.10083
Lauric acid	1	0.6075	0.6075	0.6075
Myristic acid	1	3.2033	3.2033	3.2033
Palmitic acid	1	26.403	26.403	26.403
Palmitoleic acid	1	3.2033	3.2033	3.2033
Stearic acid	1	1.541	1.541	1.541
Oleic acid	1	11.02	11.02	11.02
Linoleic acid	1	17.041	17.041	17.041
Linolenic acid	1	1.2033	1.2033	1.2033

According to Figure 3, the sesame oil has the lowest amount of oil uptake and the frying oil has the highest amount of oil uptake in the product. The sesame oil showed the lowest oil uptake in 150°C and the highest oil uptake in 190°C. This process was also observed in semi-hydrogenated oil. In the case of frying oil the lowest amount of oil uptake was obtained in 190°C and the highest was obtained in 170°C.

According to Figure 4, the sesame oil and semi-hydrogenated oils had the lowest amount of oil uptake at the times of 10 and 15 min and had the highest amount of oil uptake at 5 min. Regarding the frying oil, the lowest amount of oil uptake was observed in 10 min and the highest amount of oil uptake was observed in 20 min.

Direct effect of temperature on the amount of oil uptake

According to the results, by increasing the temperature from 150 to 190°C the amount of oil uptake also increased. Gamble *et al* (2007) found that lower temperatures in the early stages of frying led to less oil uptake during frying the potato slices, given that the difference between two levels of 145 and 165°C was more than the difference between two levels of 165°C to 185°C in terms of the oil uptake.

Table 6. Analysis of variance of factors affecting the amount of changes in the fatty acids in semi-solid oil.

Name of fatty acid	Df	SS	MS	P-value
Caproic acid	1	0	0	0
Lauric acid	1	0.0033	0.0033	0.893
Myristic acid	1	0.0408	0.0408	0.819
Palmitic acid	1	1.7633	1.7633	0.301
Palmitoleic acid	1	0.6533	0.6533	0.453
Stearic acid	1	0.963	0.963	0.468
Oleic acid	1	0.48	0.48	0.773
Linoleic acid	1	1.02	1.02	0.874
Linolenic acid	1	0.001	0.001	0.98

Table 7. Analysis of variance of factors affecting the amount of changes in the fatty acids in sesame oil.

Name of fatty acid	Df	SS	MS	P-value
Caproic acid	1	0	0	0
Lauric acid	1	0	0	0
Myristic acid	1	0.2133	0.2133	0.423
Palmitic acid	1	0.021	0.021	0.951
Palmitoleic acid	1	0.0133	0.0133	0.808
Stearic acid	1	5.333	5.333	0.179
Oleic acid	1	0.368	0.368	0.855
Linoleic acid	1	3.52	3.52	0.725
Linolenic acid	1	1.1408	1.1408	0.218

Moreira (1999) found that the oil uptake is not affected by the oil temperature but frying at 190 °C had more oil uptake (5.3%) than the temperature of 155°C. Krokida *et al* (2000) stated that the oil temperature and the thickness of the potato slices have a significant impact on oil uptake and moisture loss of fried potato. The phenomenon of the loss of water and oil uptake will be more and more intense at high temperatures and less thickness of samples. Garayo & Moreria (2002) also fried potatoes under low pressure and found that the oil uptake increases by increasing temperature. Bouchon *et al.*, (2003) found that the oil uptake in the frying potatoes at three temperatures of 155-170-185°C is not significantly dependent on temperature and has Logarithmic trend. The amount of oil uptake at 170 and 185°C is significantly, P(0.335), different with 155°C, P(0.022), and oil uptake increases by increasing temperature. Also Debnath *et al* (2003) studied the effect of frying temperature and drying before frying process. The results showed an increase in temperature from 150 to 200°C leads to an increase in the mass transfer coefficient and moisture and more oil uptake. Regarding the results obtained in this study and similar studies on the role of temperature in oil uptake it can be stated that oil uptake increases by increasing frying temperature because the high oil temperature will accelerate the creation of a solid crust and consequently, provide the surface properties that are suitable for oil uptake (Garayo & Moreria, 2002). Also, in high temperature, the water loss increases and thus oil uptake increases

(Krokida *et al*., 2000). On the other hand, some researchers believe that oil uptake increases by decreasing the temperature. Pedreschi *et al* (2005) showed a kinetic model of fat uptake by the potato slices during deep frying in which the frying temperature increases the rate of water evaporation that simultaneously reduces the frying time and oil uptake. Rossell (2001) also stated that the increase in oil temperature reduces the amount of oil uptake. Kita & Lisinska (2005) found that without considering the effect of oil type, increasing the oil temperature will reduce the amount of oil uptake and reported the amount of decreasing the oil uptake from 9.11% at 150°C to 8.03% at 190°C. Kita *et al* (2007) stated that the oil uptake is dependent on the type of oil and frying temperature and the oil uptake decrease by increasing the frying temperature, regardless of the type of oil. They found that by increasing per 20°C in temperature, the amount of oil uptake is reduced by 3% on average. Some research suggests that the oil uptake decreases by increasing the frying time, because at high temperatures due to shortening the frying process and increasing the formation of the crust a barrier is made against oil uptake. The crust affects the heat and mass transfer and the physical changes, gelatination and denaturation of proteins occurs in the crust (Dina & Saguy, 2006). Also, the crust prevents from separating water from the food largely and subsequently prevents from entering oil into the product. On the other hand, the amount of oil uptake decreased by increasing the frying temperature from this sense that the food expose less time to heat (Rossell, 2001).

Table 8. Analysis of variance of factors affecting the amount of changes in the fatty acids in total of three oils.

Name of fatty acid	Df	SS	MS	P-value
Caproic acid	1	0.03361	0.03361	0.321
Lauric acid	1	0.2336	0.2336	0.395
Myristic acid	1	2.007	2.007	0.336
Palmitic acid	1	14.567	14.567	0.147
Palmitoleic acid	1	0.25	0.25	0.74
Stearic acid	1	0.003	0.003	0.985
Oleic acid	1	3.868	3.868	0.544
Linoleic acid	1	3.55	3.55	0.811
Linolenic acid	1	1.604	1.604	0.419

Direct effect on time on the oil uptake

Based on the results, the amount of oil uptake increase by increasing the time from 10 to 20 min and the highest amount of oil uptake was observed at 5 and 20 min. Krokida *et al* (2000) found that the amount of oil uptake significantly increased by increasing frying time. Bouchon *et al*., (2003) stated that the amount of oil uptake is significantly associated with the square root of frying time and the amount of oil uptake changes linearly with the frying time. Dina & Sagay (2006) stated that by passing the frying time, the amount of oil uptake increases that is due to the increased viscosity of the oil. Rimac-Brncic *et al* (2003) stated that the amount of oil uptake increases by increasing frying time, but this process is not a linear process. According to studies and researches conducted, it can be stated that increasing the oil uptake by passing the frying time is probably for the reason that the viscosity increases during deep frying and also the polymerization reaction causes to destroy the oil (Dina & saguy, 2006). Also by reminding that the oil uptake is a surface phenomenon and followed by competition between the drain and suction that is made in the porous structure of the potato slice crust during taking out of oil in the stage of cooling and includes STO, SO and PSO It is believed that during frying severe volatiles of water prevents from entering the oil into the porous structure and subsequently the oil uptake is more in the cooling stage. Also the uptake process of PSO increases by increasing the frying time and its reason is that the thickness of crust increased during frying and pores become more and thus the entry of oil into the food during the cooling period is allowed

(Pedreschi *et al.*, 2007). On the other hand, the time of 5 min had the highest oil uptake and this high uptake by food can be interpreted as followed: Given that the rate of entry and exit of oil in food production depends on the viscosity and surface tension between oil and product, oil uptake increases by increasing viscosity and increasing the surface tension will also increase the amount of oil uptake (Paul & Mittal, 1997). It can be stated that at the beginning of frying that the viscosity is high and during taking the potato out of the oil after 5 min, the surface tension between the oil and products is high, so we have high uptake in 5 min. It can also be interpreted this way that according to theory of Moreira *et al* (1999) the oil uptake occurs more during the first 10-15 seconds of frying. Also the gelatation of starch and the moisture evaporation occur with high rate and expansion of the capillary pores more than before. If after 5 min, the food is removed from the oil, the amount of oil uptake become higher due to more capillary pores and also more amount of oil sticking to the surface of food. In another study, Ziaiifar (2008) noted that in the initial stage of frying, water evaporation increases and bubbles will be formed and makes the driving force within the oil and the oil replaces the evaporated water and this replacement causes a net turbulence flow in the oil. After that, the convective flow and heat transfer increases and also the amount of oil uptake increases in the early stages of frying. On the other hand, in the late stage of frying that the humidity decreases, the convection heat flow also decreased and the oil uptake process becomes slower. Fellows (2000) stated that the bubbles made can play the reverse role in heat transfer due to excessive moisture loss. He also said that the big bubbles that will not go away product create resistance to heat transfer quickly and reduce oil uptake. So the reason of the least amount of oil uptake after 10 min could possibly be justified considering this. It seems that the reason for increasing the oil uptake in 20 min is that the oil is placed under high heat for 20 min and since it is placed under moisture and oxygen, it is oxidized and produces the decomposable products titled volatile and non-volatile decomposable products. Non-volatile decomposable products are formed as deposition around the fryer and polymerization produces the cyclic compounds with a high molecular weight in the absence of oxygen that increases the viscosity of oil and the amount of oil uptake increases by increasing viscosity (Rossell, 2001).

Table 9. Mean comparison of fatty acids at different temperatures.

Oil type	Characteristic of sample	Capric acid	Lauric acid	Myristic acid	Palmitic acid	Palmitoleic acid	Stearic acid	Oleic acid	Linoleic acid	Linoleic acid
Sesame 150	1	-	-	-	9.2	0.8	7.4	33.3	41.2	2.2
Sesame 170	2	-	-	-	8.5	0.6	8.0	31.0	48.3	1.5
Sesame 190	3	-	-	0.8	12.4	-	5.8	36.8	39.6	2.7
Semi-hydrogenated 150	4	-	-	0.7	1.3	1.6	8.2	31.7	37.8	3.4
Semi-hydrogenated 170	5	-	0.7	1.8	14.5	2.8	9.5	35.9	28.8	4.8
Semi-hydrogenated 190	6	-	0.6	2.2	12.6	3.3	10.4	33.8	27.5	5.4
Frying oil 150	7	-	0.8	2.4	13.0	3.5	10.7	34.0	29.4	5.5
Frying oil 170	8	0.4	0.5	2.8	10.5	3.8	9.4	33.4	31.3	4.2
Frying oil 190	9	-	1.1	3.0	11.2	3.4	12.5	26.6	32.8	4.0
Sesame before frying	10	-	-	0.8	10.2	0.6	4.4	34.4	45.2	0.9
Semi-hydrogenated before frying	11	-	0.5	1.8	15.0	3.5	10.5	33.0	30.2	4.5
Frying oil before frying	12	0.5	1.7	4.8	17.5	1.5	12.3	27.5	26.4	3.3

Direct effect on the oil type on the oil uptake

According to the results, frying oil had the highest amount of oil uptake and the frying sesame oil had the lowest amount of oil uptake. Although in investigating the results of other researchers the similar cases were not found regarding the type of oil used and frying time, some research conducted demonstrated the oil type effective in the process of deep frying. Kita & Lisnska, (2005) stated that the oil type is effective in the amount of oil uptake and among the tested oils (refined sunflower- soybean- Olive- Palm- rapeseed– semi-hydrogenated rapeseed and a mixture of vegetable oils) they found that rapeseed had the lowest amount of oil uptake and sunflower oil had the highest amount of oil uptake. In studying the effect of oil type and frying temperature on the amount of oil uptake and the texture of fried potato, Kita *et al* (2007) found that the amount of fat absorbed by the potatoes is dependent on the type of frying oil. The highest amount of oil uptake was in peanut (35.9%) and lowest was in rapeseed (30.6%). Of course, there are sources indicating the lack of effect of the oil type on the oil uptake in the frying process that perhaps its main reason is the similarity of the used oil in terms of the fatty acid profile. In other research it has been stated that the oil uptake with the unsaturated oils such as cottonseed oil is weaker than palm oil. It is due to its low viscosity form during cooling and the ability to drain it the easier. This contradictions show that oil viscosity is very effective in the mechanism of oil uptake. High oil viscosity entails less oil migration. The initial viscosity of the oil depends on the temperature and type of oil (Vitrac, 2000). Based on the results of this study it can be concluded that all the research done on the effect of viscosity on oil uptake during frying agree. So, the most important factor in the oil uptake is viscosity. The different oils have different viscosities. Some researchers may believe that the lack of effect of oil type is due to its excessive reduction in the normal frying temperature but perhaps the role of viscosity during cooling of the food after frying can more be considered when the oil entered into the texture of food begins to exit from the texture and meanwhile, the temperature of food is decreasing to reach ambient temperature. Changes in the viscosity of oils during frying are predictable, especially in the case of unsaturated fatty acids, the formation of dimeric and cyclic compounds have priority over thermolite reactions (Gunstone, 2004). It is noteworthy that the oil viscosity increases by increasing the amount of long-chain fatty acids. The amount of saturation also increases viscosity. Thus hydrogenation of oils is considered as one of the factors of viscosity increase and we expect that the hydrogenated or semi-hydrogenated oils had more uptakes during frying. Furthermore, increasing the length of fatty acids is one of the factors of increasing the viscosity that should be considered in formulating oils such as frying oils (Lewis, 1996). According to the profiles obtained by gas chromatography test, in studying the amount of unsaturated fatty acids in oils it can be argued that averagely the oleic acid and the linoleic acid form about 80% of sesame oil fatty acids and about 63% of semi-hydrogenated oil fatty acids and about 54% of the frying oil fatty acids that are from the kinds of unsaturated fatty acids. Given that by decreasing the unsaturated fatty acids the amount of viscosity increases and by increasing the viscosity the amount of oil uptake increases, the minimal uptake of sesame oil can be related to high amount of unsaturated fatty acids in it.

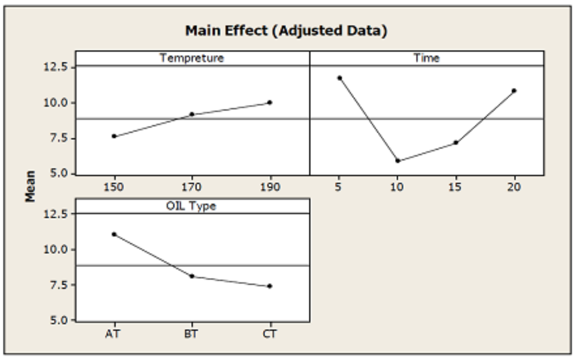

Fig. 1. Mean comparison of the effect of temperature, time, and type of oil on oil uptake.

Chromatography test results

The amount of changes in three oil fatty acids (separately) after 20 min heating was examined by analysis of variance.

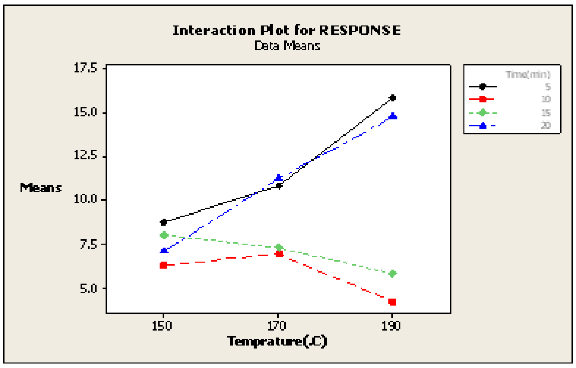

Fig. 2. Mean comparison of interaction of temperature × time on the oil uptake.

According to Table 5, using the GLM method in the minitab software there is no enough evidence to reject the null hypothesis (the equality of mean value of each fatty acid before and after heating at frying oil), (except myristic acid and palmitoleic acid that have the P-value less than 0.05).

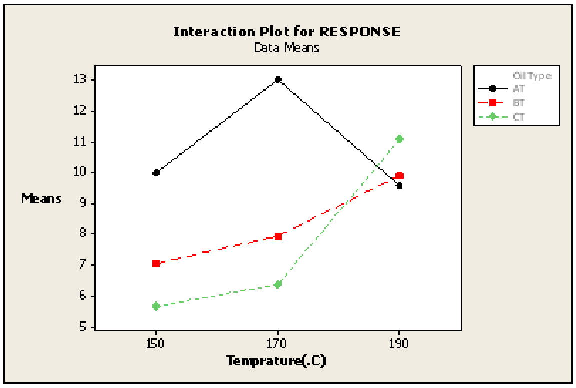

Fig. 3. Mean comparison of interaction of temperature × oil type on the oil uptake.

According to Table 6, using the GLM method in the minitab software there is no enough evidence to reject the null hypothesis (the equality of mean value of each fatty acid before and after heating at semi-solid oil) considering the amount of P-value that is more than 0.05.

According to Table 7, using the GLM method in the minitab software there is no enough evidence to reject the null hypothesis (the equality of mean value of each fatty acid before and after heating at sesame oil) considering the amount of P-value that is more than 0.05.

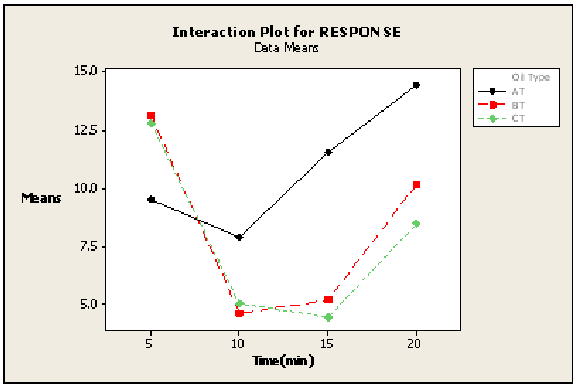

Fig. 4. Mean comparison of interaction of time × oil type on the oil uptake.

According to Table 8, using the GLM method in the minitab software there is no enough evidence to reject the null hypothesis (the equality of mean value of each fatty acid before and after heating at semi-solid oil) considering the amount of P-value that is more than 0.05.

Studying the effect of changes in oil fatty acids on oil uptake by food

Studying the data obtained from analysis of fatty acid profiles of three types of oil used does not show a significant difference between the ratios of different fatty acids before and after frying at three test temperature and maximum time used (20 min). This means that the ratios of fatty acids in all three types of oil have remained unchanged separately as well as in the study of total of three oils (at least by gas chromatography). Therefore, the changes in the amount of oil uptake in different oil and different time cannot be related to the change in the ratio of fatty acids during the frying process. This research suggests that at least up to 190°C and 20 min, these three types of oil (sesame, semi-hydrogenated and frying) do not suffer a significant structural changes in terms of fatty acid profiles and the theory of effect of these changes on oil uptake during frying process is rejected.

Conclusion

The results of test conducted suggest the effectiveness of type of oil chosen on the amount of oil uptake followed by the process of deep frying the potato samples. Some sources have not significantly considered this point and considered the selection of oil type ineffective on the oil uptake and knew its reason the lack of significant difference in the viscosity of all types of oil at frying temperature while remaining and no exiting oil during cooling the product after frying is a very important and influential step in the amount of oil in the fried product. On the other hand, the lowest amount of oil uptake was observed during frying at 150°C for 10 min and for sesame oil.

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